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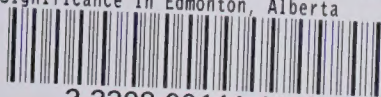
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Study of Air Pollution Sources and Their
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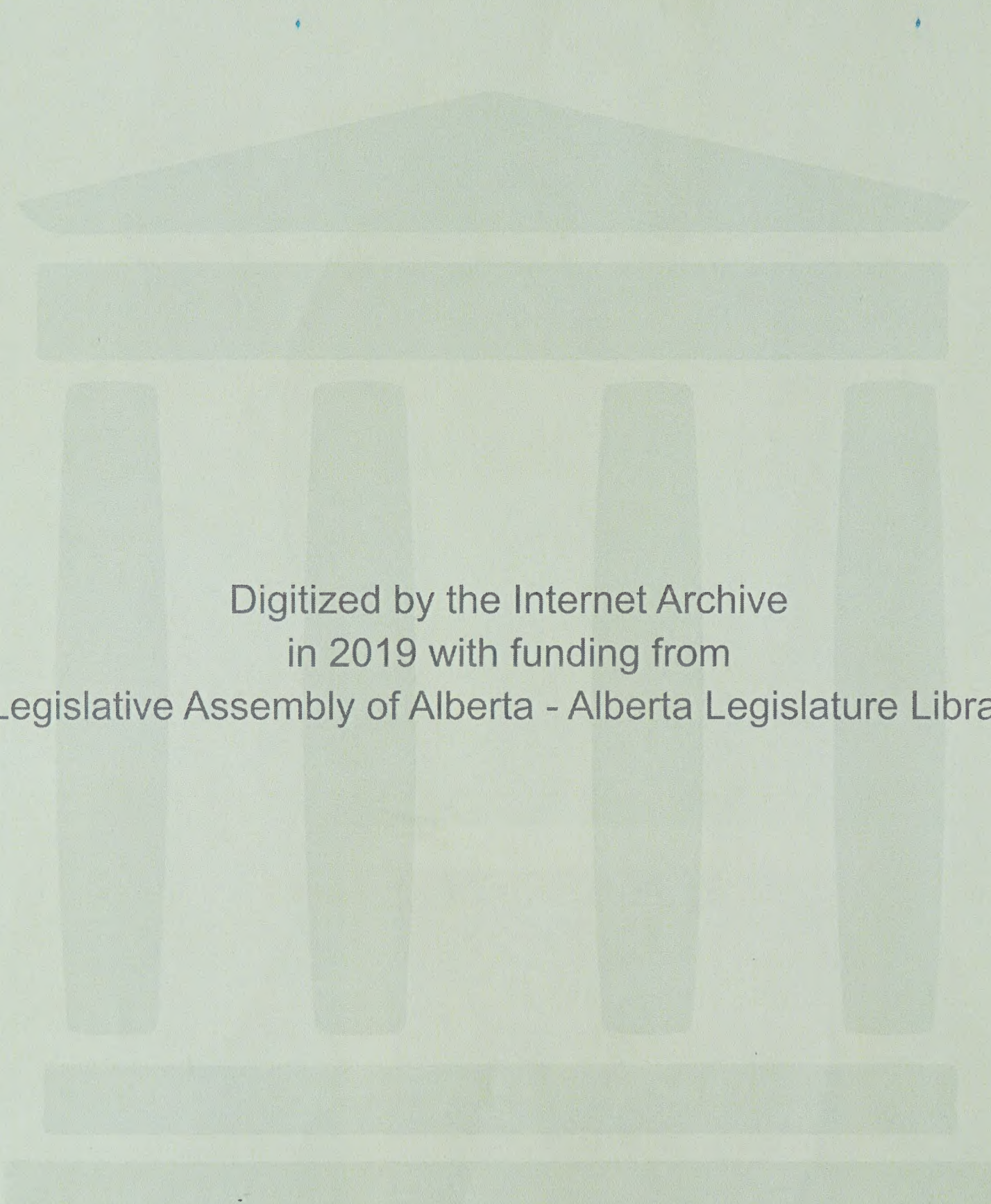
A Study of Air Pollution Sources and Their Significance
in Edmonton, Alberta

Government of the Province of Alberta
Department of Public Health
Division of Sanitary Engineering
Administration Building
Edmonton, Alberta

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PROVINCE OF ALBERTA
DEPARTMENT OF PUBLIC HEALTH
Division of Sanitary Engineering

MINISTER OF EDUCATION: OCT 30 1964

Administration Bldg.,
Edmonton, Alberta.

October 16, 1964.

Hon. Randolph H. McKinnon,
Minister of Education,
Department of Education,
Room 702,
Administration Building,
EDMONTON, Alberta.

HUMAN RESOURCES RESEARCH COUNCIL
11507 - 74 AVENUE
EDMONTON 62, ALBERTA

Dear Sir:

Re: Air Pollution Control, City of Edmonton
and Surrounding Areas

Further to the continuing studies of air quality and the air pollution control requirements contained in the Provincial Board of Health Regulations for the Control of Air Pollution passed in 1961, a study of the sources of emissions has been carried out during the summer of 1964. A report on this study has now been completed and a copy is forwarded herewith for your information.

The report will be largely self-explanatory, however we would emphasize that this report is only a part of the continuing provincial program for the control of adverse air pollution throughout the province and specific requirement to all industries and municipal activities having an air pollution significance is not anticipated at this time. Continuing studies and also evaluation of the significance of the emissions from specific industries will be required before full assessment of the emissions and their significance can be made.

There are, however, a number of sources of air pollutants which have been noted in the report and also in other studies of air pollution which are causing particular local problems and have a significant effect on the quality of the air in the general Edmonton area. It is proposed to require correction of these practises at an early date.

One of the highlights of the report is the section on hydro-carbon emissions in the area and these will receive special study in the immediate future.

THE UNIVERSITY OF CHICAGO
DIVISION OF THE PHYSICAL SCIENCES
DEPARTMENT OF PHYSICS

CHICAGO, ILLINOIS
JANUARY 1954

MEMORANDUM FOR THE RECORD

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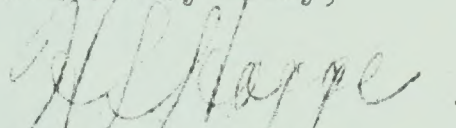
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It should be noted that while the Provincial Department of Health has been taking a leading role in the formulation of suitable air pollution control practises, much valuable assistance and advice has been received from the staff of the City of Edmonton, in particular the City Board of Health and the City Engineering Department.

We trust that you will find this report of interest. Should you desire further information on any particular aspects, the Division of Sanitary Engineering will be pleased to supply additional information if it is at all possible.

Yours very truly,

A handwritten signature in cursive script, appearing to read "H. L. Hogge".

H. L. Hogge, P. Eng.,
Provincial Sanitary Engineer.

HLH:ad

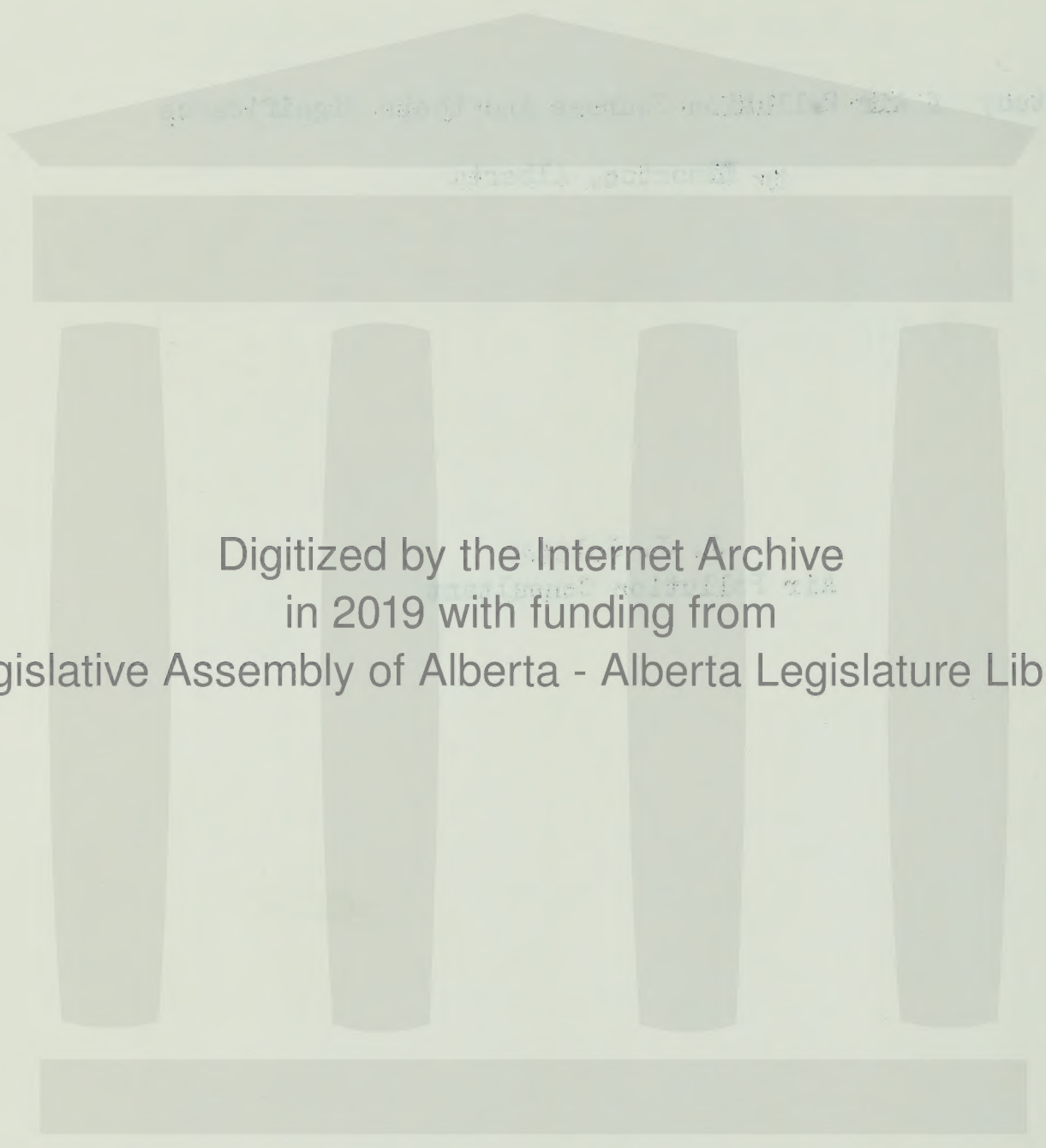
Encl.

A Study of Air Pollution Sources and their Significance
in Edmonton, Alberta

J. J. Rolston
Air Pollution Consultant

Government of the Province of Alberta
Department of Public Health
Division of Sanitary Engineering

August 31, 1964



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ACKNOWLEDGMENTS

Grateful appreciation is extended to those individuals and agencies whose co-operation and generous supply of data made possible this study and report.

Honorable J. Donovan Ross, Minister of Health.

The industries in the Edmonton area who provided data for this survey.

Staff of the Air Pollution Control District, County of Los Angeles.

Mr. B.R. Ford, Jr., Senior Air Sanitation Engineer,
Bureau of Air Sanitation, State of California,
Department of Public Health.

Staff of the R. A. Taft Sanitary Engineering Center,
U.S. Department of Health, Education and Welfare.

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A Study of Air Pollution Sources and Their Significance
in Edmonton, Alberta

Summary

In May, 1964, a survey of the pollutant sources in the Edmonton area was begun. The survey utilized a questionnaire which was mailed to 210 specific sources. The principal objective of the study was to provide current data on the quantity and types of air pollutant sources, and to evaluate their contribution to air pollution in the Edmonton area.

The data obtained indicates that in general the quantities of pollutants emitted to the Edmonton atmosphere per sec are not present in great enough quantities to create individual area problems. The only exception is hydrocarbon, which under certain conditions may achieve concentrations which are considered adverse (a).

Industrial development in Edmonton has resulted in establishment of many industries which process organic materials. The emissions expected from these industries are compounds which are expected to be capable of entering into photochemical reactions which produce smog. Furthermore, the abundance of raw materials such as natural gas, would indicate that future development would include a significant portion of similar industries.

As a result the smog formation potential in Edmonton is considered high.

Although present emissions appear in general to be low, total quantities are considered high for a city of Edmonton's size. In the event that the accelerated growth of population and industry continues, air pollution problems can be expected in the future because of increasing pollutant emission.

(a) State of California, Ambient Air Quality Standards.

Recommendations:

Based on the results of the source survey, the expected growth of Edmonton, and the importance of conserving our air resources, it is recommended that the following be carried out in Edmonton:

1. Hydrocarbon emissions be controlled in the Edmonton area. This can be accomplished by:

- A. Control of incineration of garbage and refuse.
- B. Control of the emission of hydrocarbons by the petroleum and petrochemical industry.
- C. Co-operation of the Canadian automotive industry in controlling motor vehicle exhaust emissions.

2. The present air monitoring network be expanded to include:

- A. Measurements of upper atmosphere temperatures (or inversion observations) on a continuous basis.
- B. Measurement of "Oxidant Index" on a continuous basis.
- C. Measurement of carbon monoxide and aldehyde concentrations in the ambient atmosphere.

3. Elimination of pollution sources which contribute to localized problems.

Industries such as asphaltic concrete plants, plastic plants, meat packing plants and rendering plants all are capable of causing local problems.

These problems can be eliminated or minimized by the use of control equipment or careful plant location.

4. Continued Surveillance of New Industry.

The present regulations require that new industry receive Provincial Board of Health approval of pollution control facilities. Continuation of this policy should aid in maintaining emission increases at a minimum.

5. Increase Source Sampling Surveys.

The information gathered in this manner is useful in evaluating pollution potential of presently existing and future industries.

Introduction

Edmonton, often referred to as the Oil Capital of Canada, ⁽¹⁾ is the most northerly city of its size in Canada. In the years subsequent to World War II Edmonton's population and industrialization advanced rapidly. At the present time some 350,000 persons live in Edmonton and the city is the most heavily industrialized center in Alberta. Edmonton's rapid industrialization was due to two factors:

1) The climate is conducive to successful farming and agricultural activities.

2) The city is located in the midst of one of the largest concentrations of oil wells in Canada ⁽²⁾.

As a result a wide variety of industrial operations have located in the Edmonton area, for example:

1) Two major pipeline terminals

2) Three oil refineries capable of processing some 50,000 barrels of raw material per day

3) A petrochemical complex representing an investment of some 100 million dollars

4) A large ore processing and industrial chemical plant

5) Several cement plants, steel processors

6) A rather heavy concentration of plastic processing plants

7) Many other industries in a variety of sizes

Late in 1959 the Provincial Government, recognizing that the heavy industrialization of Edmonton could result in atmospheric pollution problems, started an air pollution control programme in the city. The programme was to utilize staff members of the City Health Department, surrounding municipal (now county) Health Units, and the Department of Health, Division of Sanitary Engineering. Initial studies were limited to the

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measurement of smoke, sulfur dioxide, dustfall, and hydrogen sulfide at various locations in the city. As time went on the programme was gradually expanded to a point where the following atmospheric pollution investigations are carried out:

- 1) Measurement of oxides of nitrogen.
- 2) Measurement of oxidant.
- 3) Expansion of smoke, sulfur dioxide, dustfall, and hydrogen sulfide sampling network.
- 4) Measurement of total particulate matter in the atmosphere.
- 5) Investigation of specific pollutant sources.
- 6) Complaint investigations.
- 7) Visual observation of smoke sources.

In 1961, the Provincial Legislature passed a set of regulations (a) related to atmospheric pollution control.

These regulations placed control of air pollution in the hands of the Provincial Board of Health and required that:

- 1) All new industries locating in Alberta submit plans of their proposed plants to the Board for approval of the air pollution control facilities.
- 2) All existing industries, within a period of 5 years (1966), submit plans of their installation for atmospheric pollution control approval.
- 3) The emission of various materials be maintained at prescribed levels.

In late 1963 it became evident that in a very short time the Provincial Board of Health would be required to review the pollution control facilities of various industries which presently existed in Edmonton.

(a) "Regulations for the Control of Air Pollution" Alberta Regulation 572/57

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Although atmospheric sampling had been carried out in Edmonton very little attention had been paid to specific sources. As a result little information was available on the number of sources, their emissions, control equipment best suited for particular sources, or the magnitude of the problem. Furthermore, there was scant definite information available to indicate whether the Regulations passed in 1961 were as fair or comprehensive as the present situation required. It was decided therefore that the quickest solution to this problem involved the use of source inventory.

The Source Inventory

The principal purpose of a source inventory is to provide data on the number and type of sources, the volume of various contaminants emitted, and the location of specific air pollutant sources. Such information can then be used to evaluate the magnitude of the problem, determine the relative importance of individual or collective sources, evaluate control procedures, and determine the amount of control necessary to prevent the occurrence of air pollution problems.

Methodology

There are two general methods of conducting source inventories (3):

1) The historical basis whereby data accumulated by other control agencies is applied, with the use of good judgment, to the area in question.

2) The total knowledge basis where extensive information is developed by means of careful study of each individual process. This type of study requires a long time to complete and is costly.

The former type of study was chosen for Edmonton since time was not available to develop the type of data required for a total knowledge study, and a great deal of historical material was available in the form of published reports.

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The source emission inventory as carried out was broken down into four processes: literature research, use of an industrial questionnaire, stack sampling at specific industries, and application of experienced estimates of pollutant emissions.

Literature Research

The literature research which was carried out involved the use of the Division's library of pollution control publications. The literature which was available provided ample data for estimating emissions from most of the Edmonton sources (3,4,5,6). In addition considerable information was available as a result of personal communication with staff of the U.S. Public Health Service and the Los Angeles County Air Pollution Control District.

Questionnaire

The questionnaire used in this study was designed to provide the data necessary for calculating emissions, and encourage the various industries to reply to it. This was accomplished by:

1) Making the first two pages very easy to answer by the use of routine questions. It was hoped that this would encourage a more complete response.

2) Providing a section which did not require detailed estimates of emissions and therefore could be utilized by those industries not having technical knowledge of their air pollution emissions. A second section was included which could be used by those industries which had technical knowledge of their emissions.

In general it was hoped that the questionnaire was simple enough that industries which had little or no technical knowledge could provide useful data, and yet, detailed enough so that the more technically competent, larger industries would be able to provide useful information. The questionnaire

was therefore attempting to serve two purposes, and as a result was not a complete success. Experience with this survey would indicate that a two questionnaire survey, one for each industry type (technical - non-technical) would serve a more useful purpose. A copy of the questionnaire, and the letters which accompanied it are presented in Appendix A.

The questionnaire mailing list was compiled from the 1963 edition of the Edmonton Industrial Directory ⁽⁶⁾, the telephone book, and other sources. Since sources of pollutants located outside the city boundaries can affect Edmonton's air quality, industries within five miles of the boundary and those at Fort Saskatchewan were included in the survey. There are about 630 industries listed in the Industrial Directory, and contacting them all presented a gigantic task, which the time allotted to the survey did not allow for. As a result a weeding out process was conducted whereby those industries which were obvious non-emitters, or emitted relatively innocuous materials (e.g. bakery odors) were omitted.

Questionnaires were sent to some 210 specific industries in the classifications outlined in Appendix B. Replies were received rather slowly. Table I outlines the sequence of events carried out during the survey, and lists the replies received at various stages. One hundred and seventy industries replied, twenty four could not be located or had discontinued operation, and sixteen did not return the questionnaire.

Table I - Survey Sequence of Events, and Rate of Questionnaire Reply

Date	Event	Replies Received, %
May 19, 1964	Questionnaire mailed	
May 29		40
June 4	Letter reminder mailed	50
June 25		67
June 25-30	Telephone reminder	
July 20		83
July 31		92

Note: Industries which were not located or had discontinued operation were considered as replies.

Generally, most of the industries which did not reply to the questionnaire were small, and it is reasoned that their failure to reply resulted from difficulties in answering the questions or indifference.

Stack Sampling Programme

Previous to the survey several stack sampling surveys had been conducted at a few industrial locations. During the survey samples were taken at two locations, however the data provided in one of the cases was not complete, and therefore not utilized. Further stack sampling should be carried out to evaluate the emission estimates arrived at during this survey.

Experience Estimates

Early in the survey it was evident that many industries were not only unaware of the quantities of pollutants emitted, but did not realize that they emitted pollutants. Certain of the larger industries were able to provide comprehensive estimates of their emissions; however they were in a minority, and many emissions were estimated. In making these estimates the effect of local conditions was considered and attempts to correct emission factors made.

Survey Results

The industries contacted were divided into fourteen categories as outlined in Appendix B. In addition three other pollutant sources were evaluated: disposal of garbage and refuse, combustion of fuel, and the motor vehicle. The number of industries reporting in each category is outlined in Table 2, and the results of the survey follow.

Table 1 - Breakdown of Industries Which Replied to the Industrial Questionnaire

Industrial Classification	Replies
1) Petroleum & Petrochemical Development, Processing and Marketing	7
2) Industrial Chemical Manufacturing, and Processing	13
3) Food Processing	21
4) Inedible Animal and Vegetable By-Product Processing	4
5) Paints and Related Materials, Manufacturing, and Handling	2
6) Plastics, Rubber, and Resin Processing	13
7) Metal Melting and Reclaiming	6
8) Surface Finishing & Coating	7
9) Mineral Processing	33
10) Woodworking and Furniture Manufacturing	17
11) Commercial Activities	15
12) Vehicle Manufacturing and Servicing Facilities	3
13) Metal Fabrication	19
14) Textile, Fabric, Fiber, Monofilament Manufacturing and Processing	5

1. PETROLEUM AND PETROCHEMICAL DEVELOPMENT, PROCESSING AND MARKETING

There are 10 installations in the Edmonton area which fall within this classification:

- 1) Three refineries
- 2) One re-refiner
- 3) Two petrochemical plants
- 4) One gas processor
- 5) Three tank farms

These industries employ from 1450 to 2400 employees, and all submitted data necessary for the calculation of emissions. The complexity of the processes involved in most of the industries make an exact estimation of emissions impossible, however the emission factors outlined in Appendix C were used to evaluate this category.

Sources of Pollutants and Their Control

1. Petroleum Refining

The quantity and type of pollutants emitted from petroleum refineries vary considerably depending upon the refinery. These variations generally are dependent upon capacity, crude oil composition, processing practices, air pollution control measures in effect, maintenance, and housekeeping. Table 3 outlines potential pollutant sources, and indicates the operation from which they are usually emitted. Many of these substances can cause odors, property damage, and a reduction in visibility. Further, the emission of oxides of nitrogen and hydrocarbons can, if present in sufficient quantities, play a major role in the production of photochemical smog ^(1,2). In addition to the sources mentioned in Table 3, petroleum refineries are from time to time forced to flare or burn various substances. Combustion of these substances may result in the emission of smoke which darkens the sky.

Table 3 (a) - Potential Sources of Specific Emissions
from Oil Refineries

<u>Emission</u>	<u>Potential Sources</u>
Oxides of Sulfur	Boilers, process heaters, catalytic cracking unit regenerators, treating units, H ₂ S flares, decoking operations.
Hydrocarbons	Loading facilities, turnarounds, sampling, storage tanks, waste water separators, blow-down systems, catalyst regenerators, pumps, valves, cooling towers, blind changing, vacuum jets, barometric condensers, air blowing, high pressure equipment, process heaters, boilers, compressor engines.
Oxides of Nitrogen	Process heaters, boilers, compressor engines, catalyst regenerators, flares.
Particulate Matter	Catalyst regenerators, boilers, process heaters, decoking operations, incinerators.
Aldehydes	Catalyst regenerators.
Odors	Treating units (air blowing, steam blowing), drains, tank vents, barometric condenser sumps, waste water separators.
Carbon Monoxide	Catalyst regeneration, decoking compressor engines, incinerators.

(a) Atmospheric Emissions from Petroleum Refineries, A Guide for Measurement and Control. U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 763, 1960.

The following section deals with specific sources and their control.

A. Storage Tanks

Storage tanks emit a significant volume of hydrocarbon vapors, the amount being dependent on the vapor pressure of the stored liquid, tank construction, outside finish of the tank, outage and throughput. The vapors are emitted as a result of tank breathing caused by temperature changes, evaporation, and displacement during filling. Control can be effected by the use of floating tank roofs, and vapor recovery or disposal systems in

conjunction with pressure tanks. Floating roof tanks are capable of reducing emissions by 85% whereas vapor collection systems are theoretically 100% efficient.

During catalytic cracking carbon is built up on the catalyst, and as a result catalyst regeneration is carried out by means of controlled combustion. The regeneration process results in the emission of catalyst dust, carbon monoxide, hydrocarbons (methane), and sulfur oxide. Generally, regeneration is also accompanied by the emission of a visible plume which is believed to result from a condensation reaction between water vapor and various gaseous pollutants.

The emission of particulate matter is easily controlled by the use of high-efficiency cyclones, or electrostatic precipitators. Hydrocarbons, carbon monoxide, and visible plumes can most economically be controlled by the use of waste heat, carbon monoxide boilers.

C. Pipeline Valves and Flanges

Valves leak both liquid and vapor hydrocarbons as a result of the action of vibration, corrosion, heat, and pressure. Tests carried out in Los Angeles indicate that flange leakage was negligible.

Control of valve leakage is a function of maintenance, and therefore should be easily kept at a minimum.

D. Pressure Relief Valves

Pressure relief valves are generally spring loaded and may reseal improperly due to corrosion. Because of their inaccessability, maintenance and observation is difficult, and considerable leakage may result before repair. Additional emissions may result from relief valve blowoffs, but these are considered unavoidable, and are therefore not considered in emission calculations.

As in the case of pipeline valves, control of pressure relief valves is a function of maintenance.

E. Pumps and Compressors

Product leakage from pumps and condensers occurs at the contact between the shaft and casing. Packing and mechanical seals are used to retard leakage, but defective packing or seal faces, or a scarred shaft may result in leakage.

Control may be effected by good maintenance.

F. Compressor Engines

The engines used to drive gas compressors are generally fueled by natural or refinery gas. As such, their operation results in the emission of oxides of nitrogen, aldehydes, hydrocarbons, and ammonia. Individual sources are generally small and therefore are difficult to control.

G. Cooling Towers

Most refineries use water cooled process heat exchangers. The hot water is in turn cooled by the use of cooling towers. Hydrocarbons may be present in cooling water because of leaks in heat exchangers. If so, cooling towers represent a source of hydrocarbon.

H. Loading Facilities

A large portion of refinery finished product leaves by way of drums, barrels, tank cars, or tank trucks. When these vessels are loaded hydrocarbons are emitted by displacement. Drips and spills can also account for some hydrocarbon emission.

Vapor collection systems can be used to control hydrocarbon emissions at loading facilities, or, in smaller installations an activated carbon adsorption system can be utilized. Disposal of the vapors is carried out by using them as auxiliary fuel, processing the vapors in a gas absorption unit, or by absorbing them under pressure in gasoline.

I. Waste Water Separators and Process Drains

Refinery wastewater usually contains varying amounts of hydrocarbons due to spills, processing leaks, drips from pumps etc., and turnarounds. It is common practice to use an A.P.I. oil-water separator to treat refinery wastewater. As the hydrocarbon-water mixture runs through the wastewater system hydrocarbons evaporate.

Emissions from the wastewater-oil separators have been controlled by the use of fixed or floating roofs. In certain cases, vapors may be collected, recovered by absorption and the absorber tail gases incinerated.

J. Blowdown Systems, Including Turnarounds, and Equipment Maintenance

Occasional repair and maintenance of process equipment is an inherent operating characteristic of refineries. Generally a turnaround is carried out once per year on the process equipment either collectively or singularly. During both shutdowns and startups hydrocarbons are vented to blowdown systems for recovery, flaring, or to the atmosphere. Storage tank inspection, and maintenance require that the tank be drained and ventilated to remove the hydrocarbon vapors.

Hydrocarbon emission from turnarounds can be effectively controlled by the use of collection systems. The vapors emitted as a result of storage tank purging could also be collected; however, the volume is relatively small, and collection would likely be very uneconomical.

K. Flares

Flares are used to burn excess product, in the event of process upsets, and during turnarounds. The major problem associated with flaring is the emission of black smoke. Steam or air injection has proven to be a very effective method of eliminating flare smoke.

L. Boilers and Process Heaters

Boilers and heaters generally use natural gas, refinery gas, or fuel oil as fuel. Emissions of sulfur dioxide and sulfur trioxide are usually encountered, the quantity depending upon the sulfur content of the fuel. In addition, varying amounts of oxides of nitrogen, aldehydes, hydrocarbons, particulate matter, and organic acids are emitted.

M. Vacuum Jets

Steam driven vacuum jets are sometimes used to maintain a vacuum in refinery process equipment. In certain cases the jet is coupled with a barometric condenser. Hydrocarbon emissions may result from the inability of the barometric condenser to condense lighter hydrocarbons.

Control can be effected by venting exhaust lines to a fume burner or boiler.

N. Air Blowing

Air blowing is used in some refineries to remove moisture, for agitation, or for asphalt production. The blowing process results in the emission of hydrocarbon vapors, and odorous compounds. Combustion of the air effluent in boilers, incinerators, or catalytic incinerators has proven effective in eliminating this source of pollutants.

In general, vapor incineration is an effective method of controlling the emission of hydrocarbons, and odors. Other control methods include process changes, installation of control equipment, and improved housekeeping.

Although control methods are available for refineries, they are expensive. For example, the incremental cost of converting a 120-foot diameter fixed roof storage tank to a floating roof is about 70,000 dollars, and the incremental cost for a new installation roughly 30,000 dollars.

In Los Angeles County where atmospheric pollution is a serious problem, oil refiners have invested some 54 millions of dollars in air pollution control up until the end of 1961 ⁽³⁾. In doing so they have, according to the Los Angeles Air Pollution Control Officer, "been equipped with air pollution control approximating the limits of engineering capability" ⁽⁴⁾. Refining capacity in Edmonton is approximately 10% of that in Los Angeles. Therefore in order for the Edmonton area refineries to provide control measures similar to those provided in Los Angeles approximately 5.4 millions of dollars would have to be invested in control equipment. The cost of control could easily vary from this figure since weather conditions are different, processes may be different, crude oil composition is different, and the price of similar pieces of equipment may differ. In any case, expenditures well in excess of one million dollars at each refinery is a very rough estimate of the cost of maximum air pollution control by refineries.

2. Petrochemical Processing

There are a wide variety of petrochemical processes, and as a result a wide variety of potential pollutant emissions. Some of which might be expected are:

- 1) Hydrocarbons
- 2) Propylene Oxide
- 3) Nitrogen Oxides
- 4) Formaldehyde
- 5) Methanol
- 6) Ethylene Oxide
- 7) Various other organic compounds

Generally many of the compounds are malodorous, damaging to property, and are capable of participating in the reaction which produces photochemical smog.

Many of the pollutants emitted by petrochemical processes can be controlled by incineration in incinerators, boilers, heaters, or catalytic combustion furnaces. Others require complex chemical collection systems.

3. Gas Processing

Air pollution problems associated with natural gas processing are greatest when hydrogen sulfide is present in the gas feed. If this compound is not present (as in the case of present Edmonton plants) air pollution potential is low. Hydrocarbons may be emitted from container loading facilities, black smoke may be emitted during emergency flaring, and mercaptan compounds may be released as a result of odorizing. Generally emissions of this nature are small and cause nuisance problems only.

4. Tank Farm - Petroleum Products Storage

There are three tank farms in the Edmonton area with a total tank capacity of 3,378,000 bbls. of petroleum product. Combined throughput is roughly 140 million barrels per year.

Emissions

Hydrocarbon vapor is emitted from storage tanks as a result of breathing and filling losses. Appendix C presents the method of calculating losses.

Control

Generally, floating tank roofs or vapor recovery systems are used to control hydrocarbon emissions from tanks. In most cases floating roofs are used for the heavier petroleum products whereas vapor recovery is employed for the control of lighter fractions. In Los Angeles, floating roofs are permissible for materials with a vapor pressure of 11 psia or less. Generally, floating roofs are expected to reduce emission by 85% while vapor recovery systems are expected to be 100% effective.

Emissions in the Edmonton Area

In calculating the emission of various pollutants in the Edmonton area several information sources were employed (5,6,7,8). Much of the information resulted from detailed work carried out in the Los Angeles area, and the direct application of this data to Alberta sources could be misleading. Differences in processing, crude oil composition, control measures in effect, housekeeping, and many others all effect pollutant emission rates. In order to avoid these problems the particular industries involve. were requested to make their own estimation of emissions. When these figures were received they were added to, where necessary, by data calculated from values arrived at in the previously mentioned studies. The pollutants which are expected to be released by the petroleum and petrochemical industries are presented in Table 4.

Table 4 - Estimated Atmospheric Pollutant Losses
from Petroleum and Petrochemical
Industry Processing in the Edmonton Area.

Component	Losses	
	Tons per year	Tons per day (1)
Hydrocarbons	50,730	139
Sulfur Dioxide	2,969	8
Particulate Matter	1,074	3
Carbon Monoxide	63,227	173
Oxides of Nitrogen as NO ₂	1,728	5
Aldehydes	79	0.2
Ammonia	217	0.6
Other Organics	1,741	5

(1) Assumes a 365 day year.

In addition to these losses, contaminants are released to the atmosphere as a result of the incineration of waste material. The losses expected in the Edmonton area are presented in Table 5.

Table 5 - Estimate of Atmospheric Pollutant Losses
from the Incineration of Waste Material by
the Petroleum and Petrochemical Industry.

Component	Losses Pounds per year
Methanol	369 - 1012
Ethylene	352 - 2684
Acetone	less than 352
Methane	1012 - 6600
Acetylene	less than 176 - 3212
Alpha Olefins (as propylene)	less than 264
Carbonyl Sulfide	greater than 132
Benzene	greater than 132
Acids (as acetic)	greater than 176
Phenols (as phenol)	greater than 352
Aldehydes (as formaldehyde)	220 - 2816
Ammonia	39 - 176
Oxides of Nitrogen (as NO ₂)	less than 4
Carbon Monoxide	8668 - 43,560
Particulate Matter	673 - 986

Petroleum and Petrochemical References

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- (6) Stanford Research Institute.
"Literature Review of Metropolitan Air Pollutant Concentration - Preparation, Sampling and Assay of Synthetic Atmosphere", Nov., 1956.
- (7) Air Pollution, Volume II, Academic Press, New York and London, 1962.
- (8) Los Angeles County Air Pollution Control District, Technical Progress Report, Control of Stationary Sources, Volume I, April, 1960.
- (9) Air Pollution Control Association TI-3 Petroleum Committee, "The Petroleum Refining Industry - Air Pollution Problems and Control Methods", Journal of the Air Pollution Control Association, Jan, 1964.

2. INDUSTRIAL CHEMICAL MANUFACTURING AND PROCESSING

There are approximately 20 industries in the City of Edmonton which handle, process, or sell industrial chemicals. Of these twenty, fourteen were contacted, and thirteen returned completed questionnaires. The six who were not contacted were judged to be sales offices only, and therefore not applicable to this survey. The industry which did not reply to the questionnaire was small, and the lack of data wouldn't adversely effect the survey. Approximately 610 to 1020 persons are employed by the 13 industries replying to the questionnaire. All of the replying industries manufacture chemicals of some sort and are scattered throughout the city.

Emissions

The industries represented in this classification are extremely diversified, and some of the products manufactured are: soaps and detergents, insecticides, chemical specialties, manufacturing and packaging of gases, chemical processes involving chlorination, and organic or inorganic chemicals. Because of the wide diversity of products and a lack of technical data it was virtually impossible to estimate emissions on a historic basis. Some references were available on the manufacture of D.D.T. ⁽¹⁾, sodium hydroxide ⁽²⁾, nitric acid ⁽³⁾, and soap ⁽⁴⁾, however the material proved to be of little use in estimating emissions. As a result the data presented in Table 6 represents the emission estimates of the larger more technically competent industries. In order for a complete emission survey of this classification to be obtained it will therefore be necessary that stack sampling be carried out at the individual locations. A certain amount of refuse is incinerated and the emissions expected are presented in Table 7.

Table 6 - Emissions Expected from the Industrial
Chemical Manufacturing and Processing
Industry

Compound	Emission Tons per year
Sulfur Dioxide	1589
Formaldehyde	4
Acetylene	2
Ammonia	710
Phenol	2
Solids (a)	356

(a) Includes sodium pentachlorophenolate, pentachlorophenol, urea, aluminum sulphate, and caustic.

Control

The control of pollutant emissions from the chemical industry can be accomplished by the use of scrubbers and afterburners. If scrubbers are employed to control emissions it may be necessary to use weak chemical solutions as the scrubbing liquid. Afterburners are effective in controlling odorous emissions, however their application should be carefully considered as their use may result in an increase in the odor problem (conversion of sulfur compounds to mercaptans). Particulate emissions can be controlled in the usual manner, that is, the use of gravity settling chambers, electric precipitators, fabric filters, or cyclones. It is anticipated that good housekeeping and maintenance would both prove effective in reducing emissions.

Table 7 - Emissions Expected to Result from the
Incineration of Refuse by the Industrial
Chemical Industry.

Compound	Emission lbs. per year
Methanol	666 - 1702
Ethylene	592 - 4514
Acetone	less than 592
Methane	1702 - 10,299
Acetylene	less than 297 - 5402
Alpha Olefins (as propylene)	less than 444
Carbonyl Sulfide	greater than 222
Benzene	greater than 222
Acids (as acetic)	greater than 296
Phenols (as phenol)	greater than 592
Aldehydes (as formaldehyde)	370 - 4736
Ammonia	66 - 296
Oxides of Nitrogen (as NO ₂)	less than 7
Carbon Monoxide	14,578 - 73,260
Particulate Matter	9394 - 13,754

References

- (1) Tl-2 Chemical Industry Committee, "Air Pollution Control in Connection with D.D.T. Production" Journal of the Air Pollution Control Association, Vol. 14, No. 3 March 1964.
- (2) Tl-2 Chemical Industry Committee, "Manufacture of Chlorine and Sodium Hydroxide", Journal of the Air Pollution Control Association, Volume 14, No. 3, March 1964.
- (3) Tl-2 Chemical Industry Committee, "Nitric Acid Manufacture", Journal of the Air Pollution Control Association, Volume 14, No. 3 March 1964.
- (4) Molos, J.E., "Control of Odors from A Continuous Soap Making Process", Journal of the Air Pollution Control Association, Volume II, No. 1, January 1961.

3. FOOD PROCESSING

This classification includes the following industries, meat smoking, packing and canning, bakeries, dairy product processors, grain and feed millers, beverage manufacturing, and pet food manufacturing. Twenty-three Edmonton establishments were contacted, and 21 replied to the questionnaire. The 21 industries which replied were broken down as follows: 9 flour and feed processors, four beverage manufacturers, seven meat processors, and one miscellaneous manufacturer. Bakeries and dairy product processors were not contacted since their emission potential was considered to be low. Employment of personnel in the industries which replied to the questionnaire ranged from 2567 - 3693.

Emissions

The pollutants emitted by industries in this classification are essentially dust, smoke, and odor. Smoke emissions are generally confined to meat smoke house operations, while odors are common to meat processing operations, and dust emissions are encountered in the flour and feed milling industry.

Smoke

The most common (and possibly only) source of smoke in this classification is packing plant smoke house emissions. It is expected that an average smoke house emits about 85,000 ft.³ per hour of effluent, containing some 20 lbs. of particulate matter ⁽¹⁾. Such an emission rate will make compliance with Provincial Board of Health smoke regulations difficult without the use of control equipment.

Odors

Odors are, in most cases, caused by small quantities of pollutants, difficult and costly to control, and easily identified by the public. Control

agencies report that of all odor causing industries meat packing and rendering plants are the sources which are complained of most frequently ⁽²⁾. In the meat packing industry, odors are usually caused by putrefaction and oxidation of the waste materials. Odors are emitted from other industries in this classification but they are not as offensive as those emitted from meat processing plants.

Dusts

The flour and feed milling industry is the major dust source in the food processing classification. There are a number of operations carried out at flour and feed mills which result in dust emissions: grain cleaning, loading and unloading of product, grinding, conveying, and milling. Dust emission will vary depending upon the cleanliness of the grain, type of processing carried out, type of control equipment used, etc. It is difficult to establish general emission criteria since the plants vary considerably, however McLouth and Paulus ⁽³⁾ estimate that about 0.3% of the grain processed is lost as dust. Table 4 presents estimates of the emission from various specific sources. In most cases grain loading and unloading causes the greatest emissions.

Studies ⁽⁴⁾ have indicated that human exposure to grain industry dusts may be associated with the incidence of bronchial asthma. In most cases however the dusts should only cause a local nuisance.

Control

Smoke control of smoke house emissions has been accomplished by the use of a low voltage electric precipitator in conjunction with a roto-clone wet type precipitator ⁽¹⁾. It is expected that the collector arrangement mentioned above should reduce smoke opacity to the 0 - 10% range, and remove from 90 - 99% by weight of the solid contaminants.

Odor controls are varied and will depend upon the particular application. Normally packing plant odors are difficult to collect and the best control device is to prevent odors from occurring by good housekeeping or by careful operating procedures. General control methods are discussed in the Inedible Animal and Vegetable By-Product section pp 4-2 to 4-3.

Dust emissions from the grain industry can be controlled by the use of cyclones, multicyclones and baghouse filters ⁽³⁾. Generally cyclones can be operated with efficiencies up to 90% providing that dust particles are not smaller than 20 microns, whereas baghouse filters can remove about 99% of all particles larger than 0.5 microns. Since the dusts encountered in the grain industry are expected to contain a significant quantity of particles smaller than 20 microns, baghouse filters are considered the better method of control. In order for the cloth bag filters to operate continuously, reverse jet cleaning must be incorporated into the design ⁽⁵⁾.

Table 8 - Estimated Emission of Pollutants from the
Flour and Feed Industries ^(a)

Process	Emission
Alfalfa Feed Mill	26.7 lbs. of alfalfa dust per ton of production.
Barley Feed Mill	20.7 lbs. of barley flour dust per ton of production.
Wheat Feed Air Cleaner	1.3 lbs. of chaff per ton of production.

(a) New York State Air Pollution Control Board, "Inventory of Air Contaminant Emissions".

The economics of control devices are difficult to predict generally, however since much of the dust being lost can be converted to valuable product the reclaimed product will pay for the collection costs. It has been demonstrated ⁽⁵⁾ that an alfalfa plant producing two tons per day of product can pay all but approximately 18% of the costs of effective control.

Emissions in the Edmonton Area

Because of the difficulties involved in establishing emission estimates for this industry many of the contaminants emitted are not catalogued. There are some 65,000 tons of grain processed in Edmonton per year which would result in an emission of 195 tons per year of particulate matter. The emissions resulting from the combustion of waste material are outlined in Table 9, while the particulate emissions expected from this classification are listed in Table 10.

Table 9 - Emissions Expected to Result from the Incineration of Waste Material by the Food Processing Industry

Compound or Group of Compounds	Emission lbs. per year
Methanol	410 - 1046
Ethylene	364 - 2775
Acetone	364
Methane	1047 - 6825
Acetylene	182 - 3323
Alpha Olefins (as propylene)	273
Carbonyl Sulfide	145
Benzene	145
Acids (as acetic)	182
Phenols (as phenol)	364
Aldehydes (as formaldehyde)	207 - 2912
Ammonia	41 - 181
Oxides of Nitrogen	4.5
Carbon Monoxide	8693 - 45,045
Particulate Matter	695 - 1019

Table 10 - Expected Emission of Particulate Matter
from the Food Processing Industry

Portion of the Industry	Emission Tons per year
Grain processors	195
Alfalfa Products	10 (1)

- (1) This assumes that air cleaning equipment which is presently in use is 80% efficient.

References

- (1) Soderholm, N., and Boun, D.E., "Air Pollution Control of Smoke House Emission in the Packing Industry", Journal of the Air Pollution Control Association, Volume 7:1, May, 1957.
- (2) Air Pollution, Volume I, Academic Press, New York & London, 1962.
- (3) McLouth, M.E., Paulus, H.J., "Air Pollution from the Grain Industry", Journal of the Air Pollution Control Association, Volume 11:7, July, 1961.
- (4) Cowan, D.W., Thompson, H.J., Paulus, H.J., & Mielks, P.W. Jr., "Bronchial Asthma Associated with Air Pollutants from the Grain Industry", Journal of the Air Pollution Control Association, Vol. 11, No. 11, November, 1963.
- (5) "Air Pollution from Alfalfa Dehydrating Mills", U.S. Department of Health, Education, and Welfare, Public Health Service, Bureau of State Services, (1960).

4. INEDIBLE ANIMAL AND VEGETABLE BY-PRODUCT PROCESSING

This category includes activities such as rendering, tanning, and dehydrating food by-products. In Edmonton there are five establishments which fall within this classification. In addition several of the meat packing plants carry out rendering operations but they have been classified as food processing industries. This industrial classification employs from 30 to 90 persons.

Emissions

Odors are an inherent problem associated with the industries which fall within this classification. In most cases, significant odors are caused by relatively low concentrations of contaminants, and are easily recognized by the public.

Rendering

Rendering is a process whereby scrap animal matter is transformed into usable by-products such as fat or tallow. The rendering process is usually accomplished by cooking ground-up scrap material at 212°F., thereby driving off most of the water vapor. The remaining solid material is separated from the fat and tallow in a variety of ways, and is used as cattle or poultry food, or as fertilizer. In most cases odors result from the storage of putrifying raw material, spillage, or the rendering process. Rendering cookers emit large amounts of water vapor and smaller amounts of fatty particulate matter and noncondensable gases. The quantities vary from installation to installation and no data are available for predicting emissions.

Tanning of Hides

The major problem associated with tanning is odor. In most cases the odor problem should not be as severe as that associated with rendering because cooking is not carried out, and the amount of putrifiable material present is very low.

Control

Since most odor problems are caused by the emission of relatively small volumes of contaminants, odor control is difficult, costly, and usually uneconomical. Odors can be controlled by the use of combustion, water scrubbers, chemical masking agents, or absorption by activated carbon (1). Of the three, masking is probably the least desirable since it is expensive and does not reduce the contaminant emission, nor prevent contaminant build-up under adverse weather conditions. Specific areas of control in this classification are discussed below.

Storage of Raw Materials

This portion of the process includes delivery and handling of the raw material. Since odors emanating from this procedure are difficult to control, and because of the amount of odorous contaminants emitted, this is thought to represent the principal odor source in the inedible animal by-product processing industry. In many cases raw materials do not arrive at the plant until they are putrid. If storage is required the condition of the raw material deteriorates, and the odor problem increases. In some cases careful scheduling, and co-operation on the part of the raw material supplier can aid in reducing the odor emission. Difficulties encountered in collecting the odorous material make control by chemical methods difficult, if not impossible. Masking could be used but its usefulness is doubtful.

Spillage

The control of spillage is a matter of careful operational procedures, and good housekeeping. Both are easily achieved, and their development is to be commended.

Processing

Control of processing emissions can be accomplished by the use of afterburners, activated carbon filters or liquid scrubbers. The disposal of scrubbing liquids is very often a problem, and this coupled with the expense involved make liquid scrubbing unattractive. The use of an afterburner-barometric condenser control device has provided good odor control in Los Angeles County ⁽²⁾. Combustion of vapors can also be accomplished in plant boilers thus eliminating the need for an afterburner. Activated charcoal absorbers have been used successfully in several applications and have proven to be a relatively cheap control method ⁽³⁾.

References

- (1) Stern, A.C. "Summary of Conference on Odor Control", Journal of the Air Pollution Control Association, 7:1 (1957).
- (2) Los Angeles County Air Pollution Control District, Technical Progress Report. Control of Stationary Sources, Vol. I, April, 1960.
- (3) Teller, A.J., "Odor Abatement in the Rendering and Allied Industry", Journal of the Air Pollution Control Association, April, 1963.

5. PAINTS AND RELATED MATERIALS - MANUFACTURING AND HANDLING

Two industries within this classification were contacted and replied to the questionnaire. Both are small in size and total employment is from 3 to 10. Emissions are accordingly small and likely to be:

(1) odorous material

(2) hydrocarbon emission resulting from organic solvent evaporation.

No emission standards have been developed since emissions vary greatly with each individual process. No waste material is disposed of by incineration.

6. PLASTIC, RUBBER AND RESIN PROCESSING

There are a total of 20 industries which fall within this classification in the City of Edmonton. The industry employs from 125 to 294 persons. Nineteen of the 21 industries were contacted and replies to the industrial questionnaire were received as indicated in Table 11. Two establishments were not contacted, since one manufactured rubber stamps, while the other appeared to be a sales outlet for plastic bottles. Both were very small businesses (1 to 5 employees), and their emission potential was considered negligible.

Table 11 - Summary of Receipts of the Edmonton Industrial Questionnaire from the Plastic, Rubber and Resin Processing Industry

Group of Industries	Questionnaires Received
Rubber processing	2
Plastic processing	11
Unable to locate	2
Did not receive	3

Emissions and Control

Generally the emissions expected from this industrial classification will vary depending upon the process. Emissions are in most cases odorous compounds, and in certain plastic processors, particulate matter.

Rubber Processing

The industries which are located in Edmonton are concerned with tire retreading or extruded rubber products. Some odors may result from these operations and at worst should only create local nuisances. The lack of complaints from neighboring locations would indicate that atmospheric pollution problems resulting from these sources are minimal.

Plastic Processing

There are five industries in Edmonton which process plastic materials. In most cases sheet plastic is used to manufacture or form various plastic articles. Emission potential is very low.

Synthetic Resin Manufacture and Utilization

There were two industries contacted in the Edmonton area which produce synthetic resins. The processes are generally limited to polymerization, and are carried out in batch or continuous processes. Some of the resins which are produced are polystyrene and vinyl chloride. In most cases the manufacture of synthetic resins causes the emission of a certain amount of odors which have a nuisance effect. Control can be effected by the use of adequate control equipment (varies with the processes) or by locating plants in areas where public nuisances cannot be created.

The use of polymerized resins may involve crushing, grinding and conveying operations. Dust emission may result, and it is likely that control will be necessary. The type of dust collection used will depend upon the character of the dust which varies with the degree of polymerization, dryness, and particle size of the resin.

In general the emissions expected from the plastic, rubber and resin processing industry are odors for which there is no quantitative measure. As a result no emission factors have been established.

Emissions in the Edmonton Area

In addition to emitting some odor this industrial classification emits a certain amount of pollutants as a result of incineration. The emissions expected are presented in Table 12.

Table 12 - Emissions Expected to be Released as a Result of
Waste Incineration by the Plastic, Rubber and
Resin Processing Industry

Compound or Group of Compounds	Emissions lbs. per year
Methanol	13 - 35
Ethylene	12 - 92
Acetone	less than 12
Methane	35 - 225
Acetylene	less than 6 - 109
Alpha Olefins (as propylene)	less than 9
Carbonyl Sulfide	greater than 4.5
Benzene	greater than 4.5
Acids (as acetic)	greater than 6
Phenols (as phenol)	greater than 12.0
Aldehydes (as formaldehyde)	7 - 96
Ammonia	1 - 6
Oxides of Nitrogen	less than .15
Carbon Monoxide	195 - 1485
Particulate Matter	23 - 34

7. METAL MELTING AND RECLAIMING

This section deals with metal melting facilities such as grey iron, steel, brass, and aluminum foundries. In Edmonton, six establishments provided data for the survey, and data concerning two others was on file. The industry produces some 90,000 tons of finished product per year and employs from 619 - 776 employees. Metal melting activities can be divided into two classifications: ferrous and non-ferrous metal melting.

1. Ferrous Metal Melting

There are five classes of equipment available for ferrous metal melting:

- A. Blast Furnace
- B. Converters (Bessemer, and Ling-Donawitz)
- C. Open hearth
- D. Electric-Arc
- E. Grey Iron Cupola

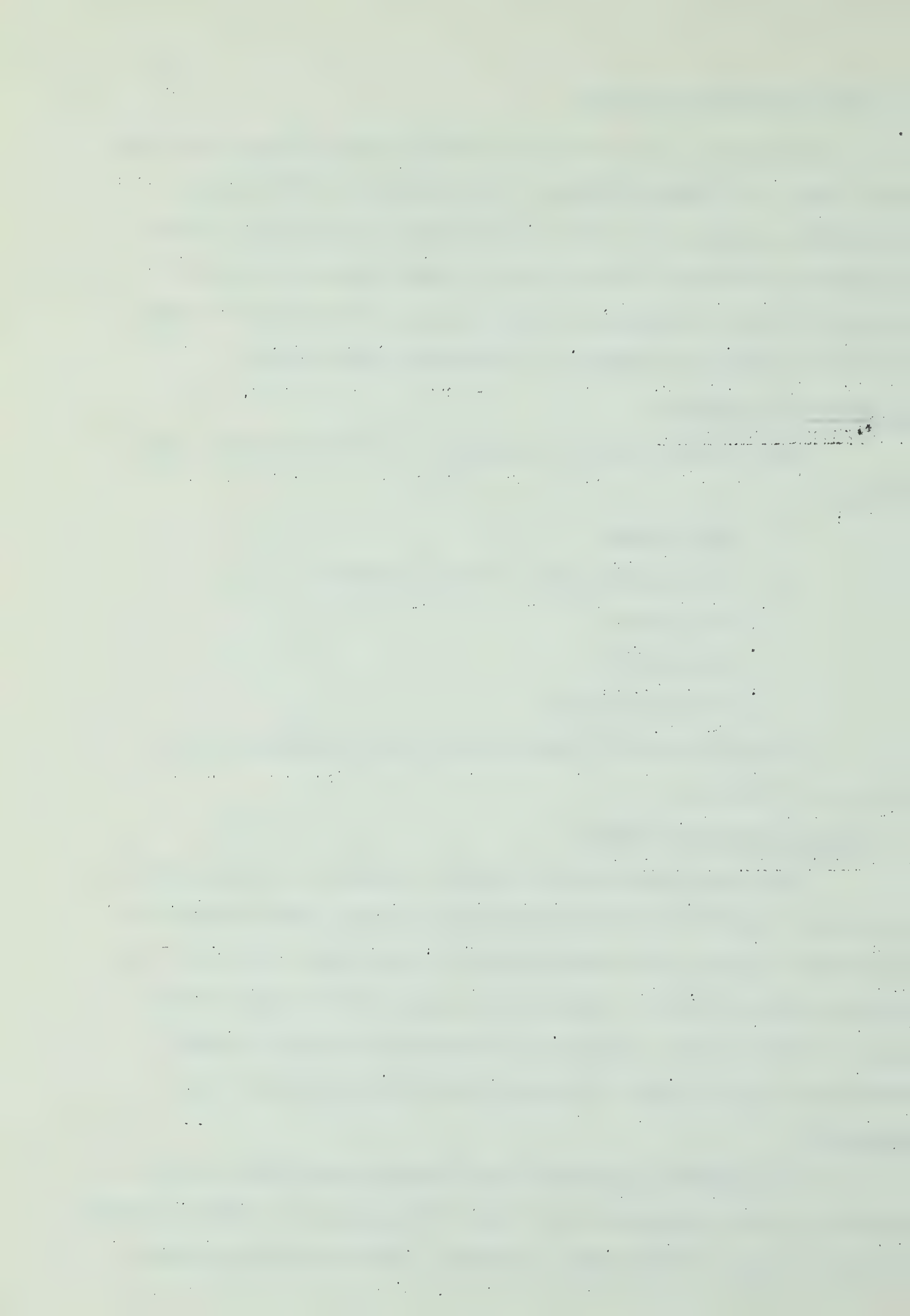
The Electric-Arc and Cupola are the type of furnaces which are being used in Edmonton.

A. Electric-Arc Steel Furnaces

Electric-arc furnances are generally equipped with three electrodes which extend into the furnace through the roof. Arcing occurs between the electrodes, and metal, thus providing the heat which melts the metal. The furnace generally tilts on rockers, or trunnions, and is charged from the top or through the side. In Edmonton, electric-arc furnaces have been installed in two locations, and produce 80,400 tons of steel per year.

Emissions

The emission pf pollutants varies widely depending upon pouring practice, pouring temperature, rate of melt d wn, sequence of material addition, and the composition of the charge. Generally, emissions are predominantly



iron oxides, but impurities in the charge (oil, dirt, other metallic elements, etc.), will result in the release of other compounds. Table 13 shows the range and composition expected. Measurement of fume emissions demonstrated a range of 4 to 37 pounds per ton of melt, and that a major portion of the particles are smaller than 44 microns (325 U.S. Standard mesh) (1,2,3,4). The particles exhibit a high angle of repose, high agglomeration tendencies, are difficult to wet, and adhere to fabric surfaces. Temperatures are expected to be in the vicinity of 2000°F.

Table 13 - Chemical Analysis Range of Electric-Furnace Dust (a)

Component	Range, %
Fe ₂ O ₃	19 - 44
FeO	4 - 10
Total Fe	16 - 36
SiO ₂	2 - 9
Al ₂ O ₃	1 - 13
CaO	5 - 22
MgO	2 - 15
MnO	3 - 12
Cr ₂ O ₃	0 - 12
CuO	less than 1
NiO	0 - 3
PbO	0 - 4
ZnO	0 - 44
Alkalies	1 - 11
P	less than 1
S	less than 1
C	2 - 4

(a) Campbell W.W., Fullerton R.W., "Development of an Electric-Furnace Dust Control System," Journal of the Air Pollution Control Association, 12:575 (1962).

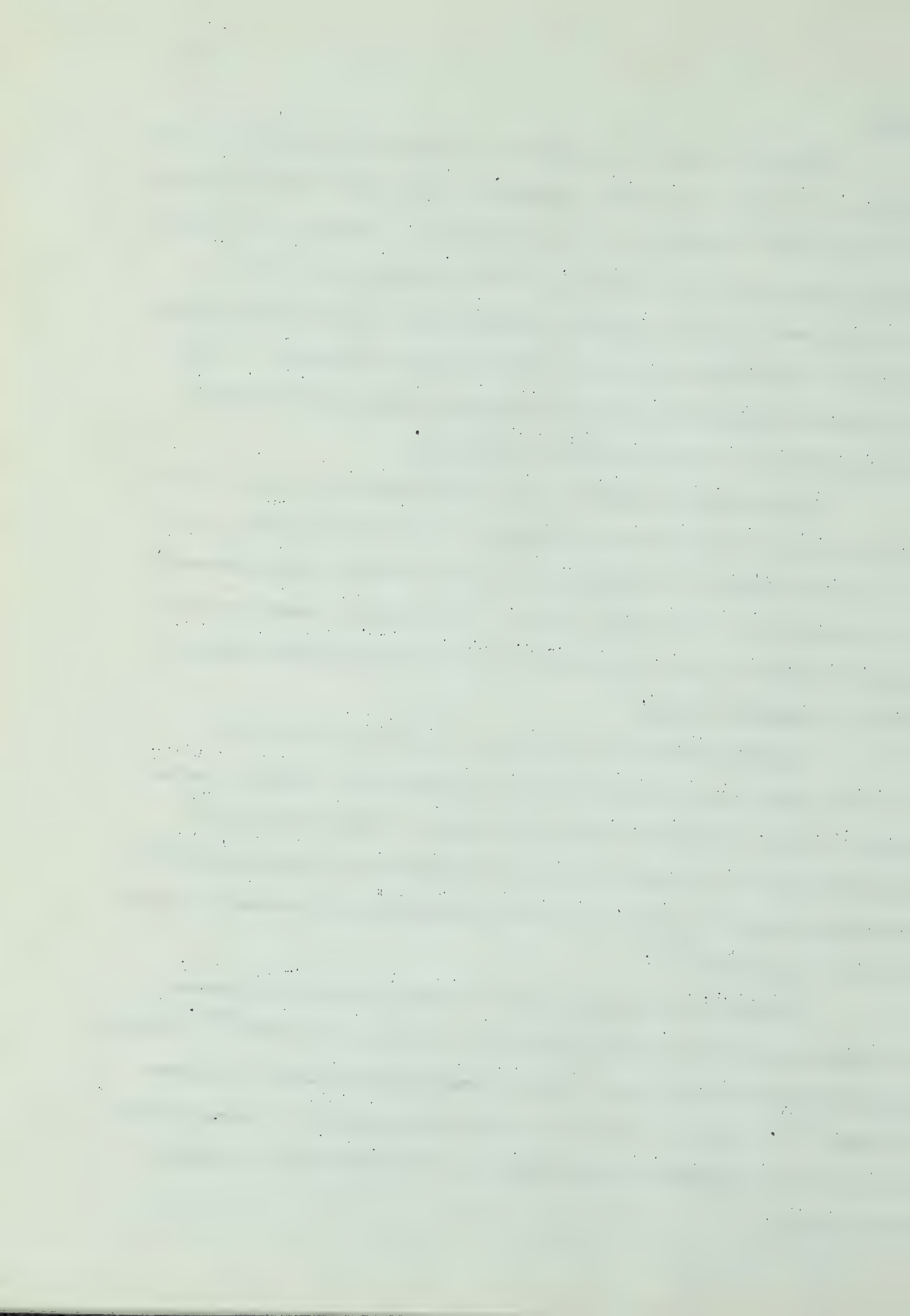
Control

Furnace design, fume temperature, and physical properties of the particles combine to make control a problem. Fumes must first be collected in a hood and then transported to the collector (7). Because of the small particle size centrifugal collectors, settling chambers, and other low efficiency devices are not capable of providing the collection efficiencies necessary to meet present Provincial Board of Health Standards. To date three types of collectors have been successfully used: wet collectors, baghouse filter, and electro-static precipitators.

Wet collectors require a high input of power, and medium initial cost, and collection efficiency is expected to be in the 62% range. The use of a wet collector necessitates disposal of a slurry of waste material, and this generally is not easily solved. In Los Angeles County most wet collectors used to control electric-arc furnace emissions have been converted to baghouse filters.

Baghouse filters are expected to have efficiencies in the vicinity of 98%, but the maximum temperature that filter fabric can withstand is 600°F. Therefore, care must be taken to ensure that the gas temperature does not exceed that which the material can withstand, and that sparks do not burn the bags. Gas cooling devices may be required to reduce the fume temperature (9).

Electric precipitators used to control electric-arc furnace emission are expected to have efficiencies of approximately 97% (2). Initial installation costs, and power costs are usually higher than for baghouse filters (7). It may be necessary to improve the resistivity characteristics of the fume by preconditioning in order for the precipitator to operate efficiently.



B. Grey Iron Cupolas

Grey iron cupolas are used at five locations in Edmonton. They can be either direct or indirect fired. The charge is usually composed of scrap cast iron, coke, limestone, and alloys which produce an iron-carbon alloy. Approximately 9,100 tons of steel are manufactured in cupolas in Edmonton.

Emissions

The solids emitted from grey iron cupolas are mainly silicon and iron, with lesser amounts of carbon, sodium, sulfur, manganese, calcium, and other metals. Emission rates vary considerably depending upon method of operation, and type of charge. Generally particulate emission of from 8.8 to 35 pounds per ton of iron produced are to be expected ^(1,2,3,4). The size distribution of the particles is presented in Table 14, which demonstrates that a significant portion of the particles are finer than 40 microns (325 U.S. standard mesh). The temperature of the gas at the furnace outlet varies from 1500 to 2000°F ⁽¹⁾.

Control

The large percentage of fine particles present in the fume does not allow for the use of centrifugal collectors or settling chambers. Experimentation ⁽²⁾ has revealed that scrubbers are ineffective in controlling cupola emissions. Electric precipitators have been found inapplicable to cupola applications because:

a) Precipitators operate best under steady state conditions, and cupola operation is not conducive to such operation conditions.

b) Preconditioning of the fume results in water spray carryover which causes excessive corrosion, and maintenance problems.

Table 14 - Size Distribution of Grey Iron Cupola Fumes (b)

Size, Microns	Percent in Fraction (By weight)
0.001 - 20	1 - 15
20 - 44	15 - 25
greater than 44	40 - 65

(b) A. J. Grindle, "The Cupola Emission Problem and Its Solution", Paper presented at the semi-annual meeting, East-Central Section, Air Pollution Control Association, Harrisburg Pa., (1953).

The most effective known method of control involves the use of a baghouse filter preceded by a gas fired afterburner ^(1,2). The afterburner is necessary to promote complete combustion of the cupola effluent gases, and thereby reduce to opacity of the plume to an acceptable level. Care must be taken in the design of the burner nozzles, and the combustion air supply. A pre-mix type of burner is preferred since it alleviates the problem of combustion air supply.

Baghouse filters are capable of handling gases up to 600°F., and as a result pre-cooling of the cupola effluent may be necessary. Dacron or orlon filter media have proven the most efficient in cupola applications, but 250°F. is the maximum temperature which they can withstand ⁽¹⁾. Materials which will withstand temperatures up to 600°F are available, however, collection efficiency is not as good.

2. Non-Ferrous Metal Melting

Aluminum, brass, magnesium, and zinc are cast in Edmonton at one location. This establishment employs 9 to 19 employees and processes from 1 to 25 tons per year of each product. The charge is melted in a gas fired cupola, and the molten metal is moulded into the required shapes.

Aluminum

Melting clean aluminum ingots creates no serious air pollution problems. If, however, aluminum chloride or aluminum fluoride are used as flux, large quantities of contaminants are emitted.

Aluminum chloride is used to degas molten aluminum. Degassing is accomplished by placing the aluminum chloride below the surface of the molten metal where it sublimes. Aluminum chloride gas escapes to the surface carrying the other gases present in the metal with it. The gaseous mixture is released to the atmosphere where it condenses to form submicron, hygroscopic, particles of aluminum chloride. The aluminum chloride then reacts with water vapor to form aluminum oxychloride, and hydrogen chloride which are extremely irritating to the mucous membranes.

Aluminum fluoride is used to reduce the magnesium content of aluminum alloys. Various fluoride compounds are discharged to the atmosphere when this compound is used to demag, including hydrogen fluoride, which is very irritating and corrosive to the skin and mucous membranes.

Emissions in the range of 2 to 5 pounds per ton of processed material are expected from aluminum melting operations (2).

Control

The use of water scrubbers, and water scrubber-electric precipitator combinations have proven inadequate in controlling aluminum furnaces (2).

Baghouse filters have proven effective for controlling demagging processes, and efficiencies in the 90% range have been achieved. Baghouses have been used to control degassing operations, but difficulties were encountered as the aluminum chloride combined with water vapor to form a cake on the filter media, and corrosion was great.

At the present time the most effective control method would appear to be a specially designed electric precipitator preceded by a caustic wash. It is estimated ⁽²⁾ that the caustic scrub removes 90% or more of the free chlorine and hydrochloric acid which in turn reduces the corrosiveness of the fume. It is necessary, however, to construct the precipitator of corrosion resistant materials, such as titanium electrodes.

Copper, Brass & Bronze

Bronze is formed by alloying copper and tin, whereas brass is an alloy of copper and zinc. There are three types of brass:

- a) Red Brass - less than 7% zinc
- b) Semi-red - 7 to 20% zinc
- c) Yellow - more than 20% zinc

In Edmonton, red and semi-red brass are used almost exclusively.

Emissions

Emissions resulting from the melting of copper alloys are generally in the form of zinc or copper oxide fumes. In most cases the temperature and the zinc content of the molten mixture are directly proportional to the quantity of pollutants emitted. Table 15 demonstrates the melting temperatures of various brass mixtures and the boiling point of copper and zinc.

Table 15 - Melting Point of Various Copper-Zinc Mixtures

	% Zinc Combined with Copper				
	0	10	20	30	Pure Zinc
Melting Point of	1981	1936	1855	1738	787
Boiling Point of	4237				1664

Thus the temperatures reached in brass melting furnaces must be in the 1800° to 2300°F. range (yellow brass requires superheating because of its low fluidity). As a result the zinc will boil in the furnace, and may flare emitting excessive amounts of zinc oxide fume. Emissions as demonstrated in Table 16 are expected during brass melting operations.

Table 16 - Emission Factors Expected From Brass Processing Operations (a)

	Aerosol Emission Factor, Pound Per Ton of Raw Material
Melting Red Brass:	
Crucible or pot furnaces	3.3
Rotary furnaces	21.3
Reverberatory furnaces	16.8
Electric furnaces	3
Melting Yellow Brass:	
Crucible furnaces	14
Electric Induction type furnaces	0.7

(a) Technical Progress Report, Air Quality of Los Angeles County, Vol. 11, Los Angeles County Air Pollution Control District.

Control

The zinc oxide emitted from brass melting is in the submicron range and this precludes the use of centrifugal collectors or settling chambers. Electrostatic precipitators have not been used to any extent but should provide effective control. Baghouse filters have been used successfully in various areas, but precooling of the furnace gases may be necessary.

Slag covers aid in reducing the emissions from indirect fire furnaces but are not popular with operators since the slag cover impairs the operators judgment of correct metal temperature. Slag covers are recommended on ladels to help reduce the emission resulting from pouring.

Zinc and Magnesium

Melting of either of these metals is not considered to create an air pollution problem. In the event that dirty scrap is used afterburners may be required to control smoke emissions.

Emissions in the Edmonton Area

Table 17 presents the particulate matter which is expected to be emitted from metal melting in the Edmonton area. A small volume of refuse is incinerated and the emissions expected are listed in Table 18.

Table 17 - Emission of Particulate Matter Expected
from the Metal Melting Industry

Source	Emission Tons per year
Electric Arc Steel Furnace	1,387
Grey Iron Cupolas	159
Aluminum Melting	Negligible
Brass Melting	Negligible
TOTAL	1,546

Table 18 - Emissions Expected to Result from the
Incineration of Refuse by the Metal
Melting Industry

Compound	Emission lbs. per year
Methanol	36 - 92
Ethylene	32 - 244
Acetone	less than 32
Methane	92 - 600
Acetylene	less than 16 - 292
Alpha Olefins (as propylene)	less than 24
Carbonyl Sulfide	greater than 12
Benzene	greater than 12
Acids (as acetic)	greater than 6
Phenols (as phenol)	greater than 32
Aldehydes (as formaldehyde)	20 - 256
Ammonia	3.6 - 16
Oxides of Nitrogen (as NO ₂)	less than .4
Carbon Monoxide	788 - 3960
Particulate Matter	61 - 90

References

- (1) Air Pollution, Vol. 11, Academic Press, New York and London, 1962.
- (2) Los Angeles County Air Pollution Control District, Technical Progress Control of Stationary Sources, Vol. 1 April, 1960.
- (3) Los Angeles County Air Pollution Control District, Technical Progress Report, Air Quality of Los Angeles County, Vol. 11, Feb., 1961.
- (4) Division of Occupational Health, Michigan Department of Health, Air Pollution Survey of Industry in Certain Portions of Wayne, Macomb, and Oakland Counties in Michigan, Dec. 28, 1956.
- (5) New York State Air Pollution Control Board, Inventory of Air Contaminant Emissions.
- (6) Campbell, W.W., Fullerton, R.W., "Development of an Electric Furnace Dust Control System", Journal of the Air Pollution Control Association, 12:575 (1962).
- (7) Pettit, G.A., "Electric Furnace Dust Control System", Proceedings of the 56th Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June 1963.
- (8) Chapman, H. M., "Experience With Selected Air Pollution Control Installations in the Bethlehem Steel Company", Proceedings of the 56th Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June 1963.
- (9) Adams, R.L., "Application of Baghouses to Electric Furnace Fume Control", Proceedings of the 56th Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June 1963.

8. SURFACE FINISHING AND COATING

Nine industries in Edmonton were classified as surface finishing and coating processes, and information was received from seven. A total of 101 to 233 persons are employed in this classification.

Emissions and Their Control

A wide variety of materials, and processes are involved in this classification. Generally three main divisions exist:

- 1) Protective coating bake ovens.
- 2) Zinc galvanizing.
- 3) Plating, oxidizing, and surface preparation.

Also included in this classification is the painting industry, however this section was considered to be too large and varied to be included in the survey.

Protective Bake Ovens

There are two installations of this type which provided survey data in Edmonton. The industries apply synthetic resin, polythene, asphalt, and coal tar protective coatings to pipe. In most cases, the material is baked after application to speed drying and provide the desired coating characteristics. Baking can be carried out in either direct or indirect fired ovens which are gas or electrically heated. A wide variety of coatings are used: enamels, lacquers, oleoresins, phenolins, polyesters, vinyls, silicone varnish, and plastisol. Oven temperatures may go as high as 600°F., but curing is generally carried out in the 250 to 350°F. range. The principal emission is odorous material, however high temperature curing may result in fume emission. Los Angeles data ⁽¹⁾ indicates that for certain coatings the release of contaminants increases linearly with temperature increases.

Control

The emissions from baking ovens can be effectively controlled in most cases by the use of afterburners. Scrubbers or precipitators are not considered to provide effective control, but activated carbon filters ⁽³⁾ provide adequate solvent emission control.

Hot Dip Zinc Galvanizing

Hot dip zinc galvanizing is a process whereby clean iron or steel is coated with a thin layer of zinc by immersing the object in molten zinc. The bulk of air contaminants emitted from galvanizing operations originate from the flux cover ⁽¹⁾, however, if the object has been poorly cleaned additional pollutants will be discharged. The contaminant which is released as a result of improper cleaning (degreasing) is an oil mist. Flux covers are used to remove the oxide film present on the article. This is generally accomplished by floating the flux on the zinc and passing the article through the flux as it is immersed in the molten zinc. Two fluxes are usually employed, ammonium chloride or zinc ammonium chloride. Both form molten zinc chloride in which ammonium chloride is absorbed, and ammonia and hydrogen chloride gas are trapped. In many cases a foaming agent such as glycerin, wheat bran, wood flour or sawdust is used to reduce flux fume emission, lengthen flux life, save flux, and reduce zinc splattering ⁽²⁾. Air contaminants are generated in a variety of methods:

1) Fumes are emitted when the flux cover is agitated or disturbed by passing the object to be plated through the flux cover. If the object is smooth and dry, flux agitation is kept to a minimum.

2) When flux is placed in the kettle it takes some time to foam. During the period previous to foaming dense fumes are emitted. The same action occurs when fresh flux is added to an existing flux cover.

3) Dusting galvanized objects with ammonium chloride (to obtain a brighter smoother finish) as they are removed from the kettle, results in the emission of dense fumes.

The expected emission from zinc galvanizing kettles is 53 lbs. of aerosol per ton of material melted. The probable composition of the emission is indicated in Table 19. The particles emitted average 2 microns in size, and display high agglomeration tendencies.

Control

Water scrubbers have been used in an attempt to control kettle emissions, however in most cases scrubbers have not been capable of providing the control necessary to meet emission standards. A combination electric-precipitator and water scrubber has been used at one location ⁽²⁾, and the results indicate that this unit may be capable of providing sufficient control.

Table 19 - Probable Composition of Fumes Emitted from
Hot Dip Zinc Galvanizing Kettles ^(a)

Compound	% Composition of Fume Weight
Water vapor	2.5
Zinc chloride (ZnCl_2)	3.6
Zinc Oxide (ZnO)	15.8
Zinc	4.9
Ammonium Chloride (NH_4Cl)	68.0
Oil	1.4
Carbon	2.8

(a) Lenke, E.F., Hammond, W.F., & Thomas G., "Air Pollution Control Measures for Hot Dip Galvanizing Kettles", Journal of the Air Pollution Control Association, Vol. 10:1.

A well designed baghouse filter will control fume emissions, but operational difficulties are sometimes encountered since the material cakes on the filter bags, necessitating special bag cleaning procedures. If oil or moisture is present in appreciable quantities, bags will be quickly made useless. It is expected that adequate cleaning of the article to be galvanized will eliminate this problem.

Plating Anodizing and Surface Preparation

The process of applying a thin layer of metal over the original surface of an object by immersing the object and two electrodes to which electric current has been applied in electrolyte is known as electroplating. Chrome plating is one of the more general applications of electroplating.

Emissions

The electroplating process results in the emission of hydrogen gas due to the decomposition of water. The rate of emission varies with installation and process but high hydrogen emissions entrain acid or alkali mists, steam, and bath constituents, which are released to the atmosphere. During chromium plating a large volume of hydrogen is evolved. The hydrogen bubbles carry with them chromic acid mist which is extremely toxic and corrosive. Specific emission rates have not been established and various operations should be reviewed individually.

Control

Mists can be removed from plating air effluents by the use of scrubbers. The rate of emission of mists can also be controlled by the use of surface active agents in the plating bath.

Emissions in the Edmonton Area

The emissions expected to result from surface finishing and coating processes are listed in Table 20. It should be noted that this is a partial emission estimate only since emission rates are unknown for

some of the processes, and the painting industry was not included. The emissions resulting from the combustion of waste material are presented in Table 21.

Table 20 - Emissions Expected from Surface Finishing and Coating Processes

Compound or Group of Compounds	Emission Tons per year
Particulate Matter	.5
Asphalt fumes	1.5
Coal Tar fume	n
Chromic acid	N.A.

n - negligible

N.A. - not available

Table 21 - Emissions Expected to Result from the Combustion of Waste Material by the Surface Finishing and Coating Industry

Compound or Group of Compounds	Emission - lbs. per year
Methanol	117 - 299
Ethylene	104 - 793
Acetone	less than 104
Methane	299 - 1950
Acetylene	less than 50 - 949
Alpha Olefins (as propylene)	less than 78
Carbonyl Sulfide	greater than 39
Benzene	greater than 39
Acids (as acetic)	greater than 52
Phenols (as phenol)	greater than 104
Aldehydes (as formaldehyde)	65 - 832
Ammonia	12 - 52
Oxides of Nitrogen	less than 1.3
Carbon Monoxide	2561 - 12,870
Particulate Matter	199 - 291

References

- (1) Air Pollution Control District, County of Los Angeles, Technical Progress Report, Control of Stationary Sources, Vol. I, April 1960.
- (2) Lemke, E.E., Hammond, W.F., & Thomas, G., "Air Pollution Control Measures for Hot Dip Galvanizing Kettles", Journal of the Air Pollution Control Association, Vol. 10:1, Feb. 1960.
- (3) Kanter, C.U., Elliott, J.H., Spencer, E.F., Kayne, N., & Leduc, M.F., "Control of Organic Emissions from Surface Coating Operations", Journal of the Air Pollution Control Association, Vol. 10:1, Feb. 1960.

9. MINERAL PROCESSING

This classification includes sand and gravel plants, concrete batching plants, asphalt paving plants, and others. In Edmonton 45 concerns were contacted and replies were received as indicated in Table 22. It should be noted that since many of the plants included in this group are portable (asphalt plants etc.) that the total located in Edmonton can vary.

Table 22 - Industrial Questionnaire Replies Received
from the Mineral Processing Industries

Industrial Group	No. of Replies
Asphalt Paving Plants	3
Sand & Gravel Sales	7
Cement Mfg. and Sales	2
Concrete & Concrete Products	16
Out of Business	2
Miscellaneous Manufacturing	3
Unable to locate	6
Did not reply	6
	<u>45</u>

Emissions and Their Control

In general, the most predominant emission in this category is dust, although under certain conditions smoke may be emitted from asphalt paving plants.

Asphalt Paving Plants

Three companies which produce asphaltic concrete replied to the industrial questionnaire. These three produce a total of 225,468 tons of asphalt per year. In addition, two other plants have been surveyed by the Division, and it is expected that two additional plants are in existence.

An asphalt batching plant is usually composed of storage bins, screening devices, conveyers, weighing equipment, a mixer, and a rotary drier. Sand and gravel are charged to the rotary drier where they are dried at 300° to 400°F. The dried aggregate is then classified according to size, mixed with asphalt, and dumped into trucks.

Particulate pollutants are emitted from various sources, the largest being the rotary drier. Other sources include: the aggregate screening and classifying system, the bucket elevator, weigh hopper, and the storage bins ⁽²⁾. If bunker fuel is used as fuel for the rotary drier some smoke may be emitted, and a greater amount of particulate matter will be emitted ⁽¹⁾.

Generally, asphalt paving plants are equipped with a small mechanical precleaner which conditions the drier effluent. If such a precleaner is used, and if careful operating procedures are observed an emission of 5 lbs. per ton of raw material is to be expected ⁽³⁾.

Control

Most asphalt plants are equipped with cyclones which are used to preclean the drier exhaust. The particle sizes encountered are such that cleaning efficiencies in the 50 to 86% range are effected by the cyclone ⁽⁴⁾. Los Angeles studies ⁽¹⁾ have indicated that scrubbers using centrifugal acceleration principals in a fluted spray chamber have proven to be the most effective control device. Baffled spray chambers have been used but they are not as efficient as the spray chambers.

Control should therefore utilize a cyclone precleaner which vents to a centrifugal type spray chamber, and the following sources should be vented to the system:

- a) the drier effluent
- b) the lower end of the drier where the fire box attaches
- c) the aggregate screening & classification system
- d) the bucket elevator
- e) the aggregate storage bins
- f) the weigh hopper

It is expected that collection efficiencies of 90 to 100% can be achieved with this type of system.

Sand and Gravel Sales

Several sand and gravel vendors carry out operations in the Edmonton area, and these operations result in a small amount of dust emission. Sand and gravel are generally obtained in a wet state, and as a result the emission of particulate matter is minimal. If the aggregate is dried in rotary driers, emissions in the 5 to 20 grains per 1000 cubic feet of air effluent are expected (1 grain = 1/7000 of a lb.). Gravel crushing operations can also result in dust emissions, however such operations are usually carried out at remote sites and should not affect any particular receptors. In many cases it is expected that the road dust caused by hauling the product on dirt or gravel roads causes a greater air pollution problem than processing of the product. Since the emissions resulting from sand and gravel operations are relatively unconfined control is difficult and emission factors are non-existent.

Cement Manufacture and Sales

Two cement manufacturing companies operate in the Edmonton area. One manufactures cement from the raw material stage while the other receives clinker which is ground in preparation for sale. The company which carries out the entire manufacturing process utilizes the wet process whereby a slurry of raw material is passed through a kiln and heated to about 2500°F. The

resulting product is cement clinker, and is similar to the material which is the starting point of the second manufacturers process. Both grind the clinker in ball mills, and the resulting material is cement which is either bagged or stored in bulk for sale.

Emissions

The principal emissions from the wet cement manufacturing process are dust, and water vapor. Both are released from the kiln at temperatures ranging from 400° to 1600°F. Kiln exhaust gases are expected to have dust emissions in the 2. to 10 grains per cubic foot of gaseous effluent range ⁽²⁾. The raw and finished grinding mills which are used to pulverize the raw materials and clinker are an additional dust source. Mill effluents are expected to have dust loadings of approximately 5 grains per cubic foot of exhaust gas ⁽⁴⁾. Most cement plants, and those located in Edmonton are not exceptions, have extensive control systems. As a result general emission standards are difficult to establish, and emissions should be determined by the use of source surveys. One of the plants in Edmonton has been extensively surveyed.

Control

Much of the particulate matter lost from cement manufacturing plants is cement, and if collected can be used in the process or sold as product. As a result contaminant control may provide economic benefits as well as atmospheric pollution benefits.

Historically, cement plants utilizing dust collectors, have used fabric filters on miscellaneous sources (such as mills, conveyers, bagging operations, etc.), and electric precipitators on kiln exhausts. Fabric filters are expected to achieve removal efficiencies in the 90 to 100% range. Much of the material collected by the filters is sold as product, and as a result most cement plants have efficient collection systems installed.

Kiln exhausts, because of their high temperatures, have in the past been an unsuitable application for fabric filtering. As a result, electric precipitators have been used for dust control. Precipitators are normally expected to provide efficiencies in the 90 to 99% range but exceptions occur. Efficiencies may be lower when heavy contaminant concentrations are encountered, large particles size aerosols are present, or when the particles have a very high electrical resistivity. Corona quenching may also cause operational problems which will reduce collection efficiencies (5).

Maintenance of precipitators is sometimes a problem since the rods may burn out due to arcing, thereby reducing the effective collection area and reducing efficiencies. Most cement plants do not carry out regular efficiency checks on dust collectors, and in the case of kiln exhausts, the condensation of the moisture entrained in the effluent gas obscures the dust particles being emitted. Thus, when the precipitator is operating at less than designed efficiencies operating personnel may not be aware of the fact.

During recent years the development of synthetic filter media has made it possible for fabric filters to be used on kiln exhausts (6). Filter media which are capable of withstanding temperatures up to 600°F have been developed, but their use may necessitate the installation of exhaust gas coolers. Therefore fabric filters should be considered for the control of future kilns located in the Edmonton area.

Concrete and Concrete Products

Industries included in this section include concrete batching plants, precast concrete product manufacturers, and small custom concrete product manufacturers. It is estimated that some 85 million pounds of cement are used yearly by the industries which replied to the industrial questionnaire.

Emissions

The main contaminant emitted is expected to be cement dust. The amount emitted will vary depending upon handling methods and is expected to range from 0.25 to 1% of the cement used (7).

Control

Control of cement dust emissions in this division is difficult because of the remoteness of sources within various operations. Generally careful handling of the cement is likely the most effective and perhaps the only control method which can be effected.

Miscellaneous Sources

There are three industries which replied to the industrial questionnaire which fall within this section. Of the three one has been surveyed by the Division of Sanitary Engineering.

Emissions

This section represents a wide variety of processes, many of which are difficult to estimate emission factors for. In most cases particulate matter is expected to be emitted, and in the case of one industry where cement is used the emissions would be similar to those expected in the concrete industry.

Control

Due to the lack of information on emissions, it is difficult to describe the necessary control devices. Generally, various dust collection devices are available, and are likely applicable to these processes.

Emissions in the Edmonton Area

Emissions from the mineral processing industry are presented in Tables 23 and 24. Estimates of processing emissions have been compiled by the use of emission factors and by actual surveys. Emissions resulting from the combustion of waste material were arrived at using the material outlined in Appendix D.

Table 23 - Estimated Emission of Particulate Matter from Various Division of the Mineral Processing Industry

Industrial Division	Emission - tons per year
Asphalt Paving Plants	564
Sand & Gravel Sales	negligible
Cement Manufacture & Sales	4100
Concrete and Concrete Products	110 - 425
Miscellaneous	85 - 100

Table 24 - Estimated Emissions Resulting from Combustion of Waste Material by the Mineral Processing Industry

Contaminant or Group of Contaminants	Emission Pounds Per Year
Methanol	256 - 655
Ethylene	228 - 1738
Acetone	less than 228
Methane	655 - 4275
Acetylene	less than 114 - 2080
Alpha Olefins (as propylene)	less than 171
Carbonyl Sulfide	greater than 85
Benzene	greater than 85
Acids (as acetic)	greater than 114
Phenols (as phenol)	greater than 228
Aldehydes (as formaldehyde)	142 - 1824
Ammonia	26 - 114
Oxides of Nitrogen	less than 3
Carbon Monoxide	5614 - 28,215
Particulate Matter	436 - 638

References

- (1) Ingels, R.M., Shaffer, N.R., Danielson, J.A., "Control of Asphaltic Concrete Plants in Los Angeles County", Journal of the Air Pollution Control Association, Vol. 10:1, Feb. 1960.
- (2) Air Pollution, Vol. II, Academic Press, New York, 1962.
- (3) Air Pollution Control District, County of Los Angeles, "Technical Progress Air Quality of Los Angeles County", Vol. II. Feb. 1961.
- (4) New York State Air Pollution Control Board, "Inventory of Air Contaminant Emissions".
- (5) Sproll, W.T., "Corona Quenching -- Its Significance in Electrical Precipitation" Preceedings, 56th Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June 1963.
- (6) O'Mara, R.F., Flodin, C.R., "Filters and Filter Media for the Cement Industry, "Journal of the Air Pollution Control Association, Vol. 9:2, Aug. 1959.
- (7) Division of Occupational Health, Michigan Department of Health, Air Pollution Survey of Industry in Certain Portions of Wayne, Macombe, and Oakland Counties in Michigan, Dec. 1956.

10. WOODWORKING AND FURNITURE MANUFACTURING

A total of 23 industries within this classification were contacted. Replies were received from 17 as indicated in Table 25. The industries replying ranged in size from those employing 1 to 6 men to those who employ from 100 to 249 workers, with a majority of them being smaller concerns.

Table 25 - Replies to the Industrial Questionnaire Received
From The Woodworking & Furniture Manufacturing Industry

Industrial Sub-group	Questionnaires Received
Millwork & Building Supplies	4
Plywood Plants	2
Cabinet & Furniture Mfg.	9
Miscellaneous	2
Out of Business or Unable to Locate	5
Did Not Reply	1

Emissions

The major pollutant emissions from this classification are hydrocarbons and the products of combustion resulting from the incineration of wood waste. A third source of emissions are planing mills, however their contribution to pollution in Edmonton is considered negligible. Although the hydrocarbon emissions which result from the use of organic solvents may form a significant portion of the total hydrocarbon emission, these were not surveyed for reasons outlined elsewhere.

The combustion of wood waste in improperly designed, or poorly operated incinerators results in the emission of large quantities of contaminants. In Edmonton, approximately 351 tons per year of wood waste material is burned in single chambered incinerators, resulting in the undesirable air pollution effects as outlined in the section entitled Disposal of Garbage and Refuse. A special type of burner has been widely

utilized in the lumber industry for consuming wood wastes known as a tepee or Reese burner. In Edmonton two of these burners are used to burn about 39,300 tons of material yearly.

A tepee burner consists of a truncated cone with height approximately equal to its base diameter. The framework is composed of structural steel, or pipe, with an inside covering of medium weight steel plate riveted or bolted together. Air openings and grates are usually provided.

The operation of tepee burners usually results in the emission of large quantities of smoke, cinder, and unburned particles. This is generally due to the fact that the temperatures achieved in the combustion zone are too low to support complete combustion. Low temperatures occur because:

- 1) The steel shell conducts heat and therefore the radiant heat which would be available from a low conductive material is unavailable.

- 2) An excessive amount of excess air is allowed to enter the burner, thereby cooling the combustion products. Excessive combustion air enters the burner as a result of:

- a. Charging door left open during firing
- b. Buckled plates causing air leakage
- c. The base of the burner may allow leakage
- d. Secondary air inlet too large
- e. Burner sized too large for fuel load.

Studies (3) have indicated that emissions of cinder ranging from less than 1, to 20 lbs. per ton of material charged are to be expected from tepee burners, depending upon their state of repair. Heavy smoke emissions are probable when excess air exceeds about 700%. The emission rate of gaseous pollutants has not been established, but it is expected that emissions in

the range expected from single chambered incinerators will approximate the emissions from tepee burners.

Control

The combustion of wood is carried out in a series of three definite steps:

- 1) Wood is charged to the burner and the moisture contained in the wood is evaporated.

- 2) The volatile portion of the wood, mainly carbon, oxygen and hydrogen compounds, is distilled off. Once distillation has occurred the distilled matter is burned in the combustion zone above the fuel pile, releasing heat.

- 3) The fixed carbon portion of the wood is burned by combining with oxygen, and thus releasing heat. A portion of the wood remains as ash. For complete combustion to occur it is necessary that enough heat is generated by the process to evaporate the moisture and distill the volatiles present in the wood. A further requirement is sufficient oxygen to support the combustion of the volatiles and fixed carbon.

There are a number of variables which can affect the efficiency of the burning accomplished in a wood waste incinerator.

A. Fuel feed rate

Ideal combustion conditions will occur if fuel is fed at the same rate that water is evaporated, volatiles are distilled off, and fixed carbon is consumed. This entails a steady feed rate and a steady rate of combustion, conditions which are extremely difficult to obtain.

If fuel is added at an excessive rate the heat required to evaporate the water vapor exceeds the heat available and inefficient burning, or extinguishing of the fire results. The heat released by the burning material is further reduced during excessive charging by the increased

admission of excess air which accentuates the problem. Periods of excessive charging are usually followed by periods of insufficient charging. Therefore, if the fire has not extinguished itself, combustion will proceed, and heat in excess of that required to burn the charged material is produced. Buckling of the structural members and plates may then result. During the initial period of excess charging, smoke and burned material are expected to be released since temperatures are not high enough to complete the combustion. Once the charge rate has been reduced and excessive heat is released, increased draft (due to the elevated temperatures) is expected to increase the air intake into the burner, which in turn increases the velocity of the combustion products. As a result ash is entrained, and thereby released to the atmosphere.

B. Underfire Air

Air must be provided to the fuel bed to evaporate the moisture and burn the fixed carbon. It would be advantageous to evaporation if this air were pre-heated, however in most cases this is not feasible. The fixed carbon which must be burned constitutes 17% of the wood, therefore the amount of air required for complete combustion of the carbon is roughly 30% of the total air requirement ⁽³⁾. It is essential that this air be provided by means of a horizontal forced air system which allows the air to be blown in circles ^(1,3).

C. Overfire Air

Approximately 70% of the total combustion air should be introduced into the burner as overfire air. It is important that overfire air be introduced tangentially so that a free vortex motion of air and gases may be established. The benefits of a free vortex have been summarized as follows ⁽³⁾.

- 1) Air acquires preheat from the walls

- 2) The velocity of the gas stream is higher and as a result

better mixing of air and combustion gases occur. This in turn results in faster

combustion, and a lower excess air requirement.

3) A longer path for unburned material is established, thus increasing retention time, which promotes a more complete combustion.

D. Other Variables

- 1) Type of charge
- 2) The effect of wind on draft
- 3) Fuel distribution

Thus, if a properly designed and operated tepee burner is used to burn wood wastes it is possible to minimize contaminant emissions. Unfortunately most tepee burners are poorly designed, and generally poorly maintained and operated. Furthermore it is doubtful if a well designed and operated unit could consistently meet regulations which are applicable to urban areas in Alberta ⁽¹⁾. Therefore, the use of tepee burners in urban areas in Alberta should be discouraged. If wood wastes must be burned in urban areas, combustion should be carried out in a properly designed multiple-chambered incinerator. Further, plants should carefully examine the feasibility of using waste wood for by-products such as ⁽³⁾:

- | | |
|-----------------------|---|
| 1) Slab fuel | } could be used for plant fuel requirements |
| 2) Hogged fuel | |
| 3) Lathes | |
| 4) Presto-logs | |
| 5) Broom handle stock | |
| 6) Pulpwood | |

Emissions in Edmonton

The emissions expected in the Edmonton area as a result of waste wood incineration are listed in Table 26. These were calculated from the emission factors applicable to single chambered incinerators.

Table 26 - Emissions Expected from the Combustion of Waste
Products by the Woodworking and Furniture Manufacturing
Industry

Compound or Group of Compounds	Emission - lbs. per year
Methanol	356,860 - 911,970
Ethylene	317,210 - 2,418,710
Acetone	< 317,210
Methane	911,975 - 5,947,650
Acetylene	< 158,604 - 2,897,625
Alpha Olefins (as propylene)	< 237,910
Carbonyl Sulfide	> 118,950
Benzene	> 118,950
Acids (as acetic)	> 158,600
Phenols (as phenol)	> 317,210
Aldehydes (as formaldehyde)	198,250 - 2,537,665
Ammonia	35,690 - 158,605
Oxides of Nitrogen	< 3,965
Carbon Monoxide	7,811,250 - 39,254,490
Particulate Matter	606,660 - 888,180

References

- (1) Correspondence with the State of California Bureau of Air Sanitation
- (2) Popovich, M., Boubel, R.W., Northcraft, M., & Thornburg, G.E., "Wood Waste Incineration" Technical Report A 61 - 3, R.A. Taft Sanitary Engineering Center, U.S . Department of Health, Education & Welfare.
- (3) Boubel, R.W., Northcraft, M., Van Vliet, A., & Popovich, M., "Wood Waste Disposal and Utilization", Engineering Experiment Station Oregon State College, Corvallis Oregon Bulletin No. 39, Aug. 1958.
- (4) Wiley, E.C., "Rating and Care of Domestic Sawdust Burners", Engineering Experiment Station, Oregon State College, Corvallis Oregon, Bulletin No. 15, July 1941.

11. COMMERCIAL ACTIVITIES

There are approximately 158 establishments in Edmonton which fall within this classification. Of this total fourteen were contacted, and all of the concerns contacted returned completed questionnaires. Many of the industries in this classification were not contacted because their emission potential was considered to be low or non-existent. Dry cleaning operations are included in this classification and they are sources of organic solvents (hydrocarbon emissions). Initially it was felt that the type of survey being carried out was not conducive to collecting data on organic solvent emissions, and as a result information regarding this contaminant was not requested. As the study progressed it became evident that the evaluation of organic solvent emissions would provide useful data. Unfortunately, at that point time was not available for conducting a survey of organic solvent users.

The industries which were contacted were chosen because it was felt that they might be releasing some contaminants. The data which was received proved this assumption wrong. Two of the industries burn waste material and the emissions expected are listed in Table 27.

Table 27 - Emissions Expected From the Commercial Activities
Industry as a Result of the Incineration of Wastes

Compound or Group of Compounds	Emissions - lbs. per year
Methanol	1440 - 3680
Ethylene	1280 - 9760
Acetone	less than 1280
Methane	3680 - 24000
Acetylene	less than 640 - 11680
Alpha Olefins (as propylene)	less than 960
Carbonyl Sulfide	greater than 480
Benzene	greater than 480
Acids (as acetic)	greater than 640
Phenols (as phenol)	greater than 1280
Aldehydes (as formaldehyde)	800 - 10240
Ammonia	144 - 640
Oxides of Nitrogen	less than 16.4
Carbon Monoxide	31520 - 158400
Particulate Matter	2448 - 3584

12. VEHICLE MANUFACTURING AND SERVICING FACILITIES

Of the industries in the Edmonton area which were contacted, three were placed in this classification. They were all concerned with the repair and maintenance of vehicles, and employ from 100 to 249 persons.

Emissions

Emissions from this classification are difficult to predict. It is expected that the use of organic solvents in painting, etc. will result in the emission of hydrocarbons, while welding operations will result in the emission of iron oxide dust. Other contaminants may be emitted but a detailed survey of each industry is necessary in order that emissions can be catalogued. Emissions due to the combustion of waste material have been tabulated in Table 28.

Table 28 - Emissions From the Combustion of Waste Material in the
Vehicle Manufacturing & Servicing Facilities Industry

Compound or Group of Compounds	Emission - tons per year
Methanol	2952 - 7544
Ethylene	2624 - 20,008
Acetone	less than 2624
Methane	7544 - 49,200
Acetylene	less than 1312 - 23,944
Alpha Olefins (as propylene)	less than 1968
Carbonyl Sulfide	greater than 984
Benzene	greater than 984
Acids (as acetic)	greater than 1312
Phenols (as phenol)	greater than 2624
Aldehydes (as formaldehyde)	1640 - 20,992
Ammonia	294 - 1312
Oxides of Nitrogen (as NO ₂)	less than 32.5
Carbon Monoxide	64,616 - 324,720
Particulate Matter	5018 - 7347

13. METAL FABRICATION

There are approximately 70 industries in Edmonton which have been classified (for the purpose of this study) as metal fabricating shops. The large number of installations, coupled with low emission potential of many of the shops indicated that there was no need to contact each individual installation. As a result 22 industries, which were judged to have the greatest pollution potential of the group, were contacted. These were generally the larger shops, and it was felt that if the expectation of low pollution potential for this industrial classification was verified by the partial survey, a complete survey would not be necessary. A total of 20 industries replied to the questionnaire, and the data received indicated that pollution emissions were very low.

Emissions

The emissions expected from this classification are:

1. A small quantity of hydrocarbons resulting from the use of organic solvents.
2. A small quantity of iron oxide dust as a result of welding operations. This dust would constitute more of an industrial hygiene than air pollution problem.
3. Various contaminants resulting from the combustion of waste material. The emissions expected from the combustion of waste material are presented in Table 29.

It should be noted that roughly 95% of this material is consumed in multiple chambered incinerators.

Table 29 - Emissions Expected to Result from the Combustion of Refuse by
the Metal Fabricating Industry.

Compound or Group of Compounds	Emission lbs./year
Methanol	19 - 47
Ethylene	19 - 125
Acetone	less than 19
Methane	49 - 303
Acetylene	less than 11 - 149
Alpha Olefins (as Propylene)	less than 15
Carbonyl Sulfide	greater than 9
Benzene	greater than 9
Acids (as Acetic)	greater than 11
Phenols (as Phenol)	greater than 19
Aldehydes (as Formaldehyde)	13 - 130
Ammonia	5 - 11
Oxides of Nitrogen	approximately 3
Carbon Monoxide	396 - 1982
Particulate Matter	34 - 48

14. TEXTILE, FABRIC, FIBER, MONOFILAMENT MANUFACTURING AND PROCESSING

There are approximately 20 industries of this type in the Edmonton area. Fifteen were judged to have little or no emission potential, and information was received from the remaining five. Those contacted were: one cardboard carton manufacturer, two glass fiber producers, one paper product manufacturer and one bedding firm.

Emissions:

Emission data was not available for the industries in this classification. Emission potential for the carton and bedding manufacturers is limited to that resulting from the burning of waste material. Emissions expected from the glass fiber manufacturing industries was estimated from data provided by the individual concerns, and was limited to formaldehyde, phenol and particulate matter. Emissions from the paper manufacturer are expected to be odorous materials and those associated with waste incineration. Specific emission data should be established by the use of source surveys at each individual location. Control of the emissions expected from these sources can be accomplished by the use of scrubbers, in the case of formaldehyde and phenol, while standard collection equipment is capable of controlling dust emissions.

Emissions Expected in the Edmonton Area:

Estimated process emissions are listed in Table 30, while the emissions expected to result from waste incineration are presented in Table 31.

Table 30 - Estimated Process Emissions from the Textile, Fabric, Fiber, Monofilament Manufacturing Industry.

Compound	Emission tons/year
Particulate Matter	306
Formaldehyde	.2
Phenol	.2

Table 31 - Emissions Expected to Result from the Incineration of Wastes by the Textile, Fabric, Fiber, Monofilament Manufacturing Industry

Compound or Group of Compounds	Emission lbs./year
Methanol	540 - 1380
Ethylene	480 - 3660
Acetone	less than 480
Methane	1380 - 9000
Acetylene	less than 240 - 4380
Alpha Olefins (as Propylene)	less than 360
Carbonyl Sulfide	greater than 180
Benzene	greater than 180
Acids (as Acetic)	greater than 240
Phenols (as Phenol)	greater than 480
Aldehydes (as Formaldehyde)	300 - 3840
Ammonia	54 - 240
Oxides of Nitrogen	less than 6.0
Carbon Monoxide	11,820 - 59,400
Particulate Matter	918 - 1344

15. DISPOSAL OF GARBAGE AND REFUSE

Large increases in urban population have heightened the problem of garbage and refuse disposal. It is expected that in cities like Edmonton, where the population is increasing rapidly, waste disposal could become a serious air pollution problem if corrective measures are not started now. At the present time incineration and sanitary landfill are the most popular methods of waste disposal. Incineration, when properly carried out, has several advantages over other methods: the volume of wastes is reduced 20 times, noncombustible residue remains, non-putridifiable material remains, and it is hygienic.⁽¹⁾ Conversely, if incineration is poorly controlled large quantities of atmospheric pollutants are released, thereby causing local and area problems.

Emissions

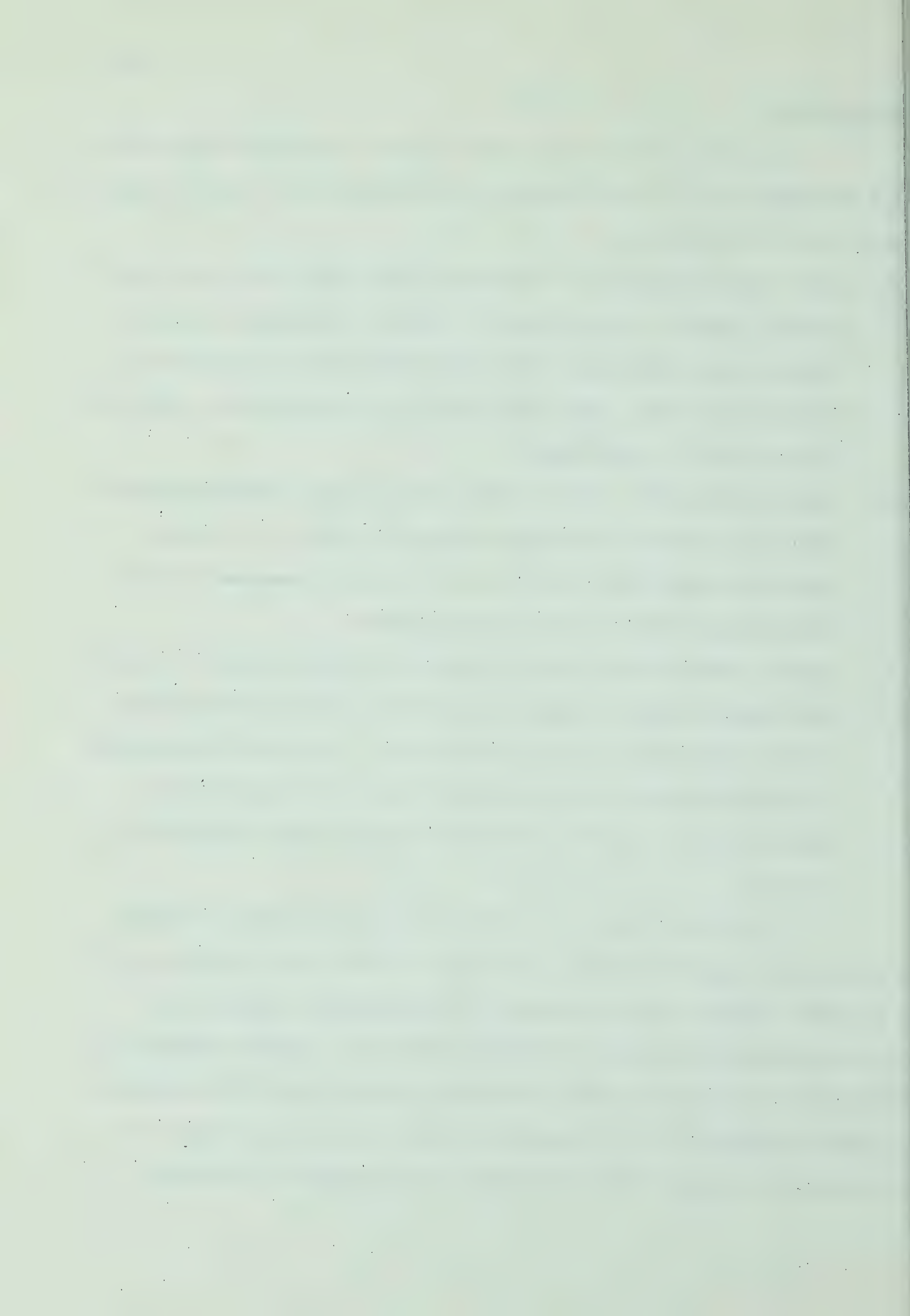
Incineration of waste material is carried out in two ways: open burning, and in an incinerator. Open burning is an extremely inefficient method of combustion and results in the release of large amounts of contaminants.⁽²⁾ Feldstein et al report that open burning results in pollutant emissions in the range which are expected from single chambered incinerators.⁽³⁾ Since it is virtually impossible to accurately measure the emissions from an open fire precise emission figures are not available. The writer is of the opinion that Feldstein's estimate is very optimistic, especially in reference to the emission of carbon monoxide, hydrocarbons, particulate matter, and formaldehyde. In any case most authorities agree that open burning is generally the most inefficient method of burning waste material.

Incinerators

Incinerators are basically heat resistant enclosures which provide for the admission of a controlled amount of combustion air. There are three basic types of incinerators:

- (1) Single chamber incinerator - Consists of one chamber which serves combustion, ignition, and ash removal. Grates are generally provided to facilitate ash removal and allow for the admission of underfire air. The control of smoke, particulate matter and volatile gases is difficult in this type of an incinerator.
- (2) Flue fed incinerator - This is essentially a single chambered incinerator with provisions for charging through the stack. As a result emission potential is similar to that of a single chambered unit plus the potential inherent to the charging method.
- (3) Multiple chambered incinerator - Composed of three chambers, an ignition and charging chamber, a mixing chamber and a combustion and settling chamber; all interconnected by flame ports. These units are designed to provide efficient and maximum combustion of the material being burned, and as a result the emission of contaminants is maintained at a minimum.

The material burned in incinerators is predominantly cellulose, with varying moisture contents, and hence, calorific value. Emissions are generally similar to those resulting from any combustion process, i.e. particulate matter, oxides of nitrogen, hydrocarbons, carbon monoxide, etc. There have been several studies carried out on the emission of contaminants from incinerators, (1,2,9,10) however, the work carried out by Yocum et al appears to be the most widely accepted, and is presented in Appendix D.



Contaminants:

Generally the emission of contaminants from an incinerator is dependent upon a combination of factors:

- (1) Design of the unit.
- (2) Combustion air supply.
- (3) Refuse composition.
- (4) Heat of combustion.
- (5) Charge rate.
- (6) Control equipment.

There are a number of references available which present detailed data on the effect of various factors upon emission rates. (2,5,6,7,8) A short discussion on some of the major contaminants follows:

(A) Particulate Matter

The particulate matter which is emitted as a result of incineration is essentially composed of fly ash, unburned carbon particles and unburned organic compounds. Emissions are generally caused by:

- (1) High velocities of combustion products which entrain fly ash, and do not allow sufficient retention time in the incinerator (hence incomplete burning).
- (2) Low temperatures of combustion products resulting from high moisture content of charge.
- (3) Inadequate mixing of oxygen and combustion products.

(B) Carbon Monoxide

The amount of carbon monoxide emitted from any combustion process is dependent upon the quality of combustion. Carbon monoxide is usually formed in incinerators as a result of insufficient oxygen being available for combustion. Studies have indicated that the distribution of air within the combustion chamber, and levels of oxygen available are the controlling factors in carbon monoxide emissions.

(C) Oxides of Nitrogen

The quantity of oxides of nitrogen emitted from an incinerator is not dependent directly upon the composition of the charged material. Oxides of nitrogen are produced by oxidation of the nitrogen in the combustion air and is, therefore, dependent upon: the amount of excess air entering the incinerator, the temperature the combustion products achieve, and the speed at which cooling is carried out. Oxides of nitrogen emissions are expected to be highest from municipal incinerators because they operate at the highest temperatures.

(D) Hydrocarbons

Hydrocarbon emissions result from the incomplete combustion of compounds which are volatilized from the incinerator fuel. Thus hydrocarbon emissions are dependent upon:

- (1) Combustion air supply
- (2) Mixing of air and combustion products
- (3) Temperatures achieved in the incinerators
- (4) Retention time of combustion products in high temperature areas.

Generally multiple chambered incinerators have lower emission potential than single chambered units.

Control

The most desirable control from an air pollution point of view would be the elimination of all incineration. Such action would necessitate the use of sanitary landfill or composting for waste disposal. Composting has several inherent disadvantages which would very likely rule out its use in Edmonton and, therefore, the use of sanitary landfill as a waste disposal device would be necessitated.

Sanitary landfill involves the filling of depressions in the ground with garbage or refuse and covering it over with a 24 inch layer of earth each day. If the landfill operation is carried out in the prescribed manner waste material can be effectively disposed of without causing the emission of contaminants to the atmosphere.⁽¹³⁾ Although sanitary landfill is a more desirable method (from the air pollution point of view) of waste disposal, incineration should not be ruled out completely.

Incineration, if properly controlled, is satisfactory for waste disposal, and in some cases is a more preferable disposal method. Generally incineration is carried out in any of four basic ways:

- (1) open burning
- (2) in a single chambered incinerator
- (3) in a multiple chambered incinerator
- (4) in a municipal incinerator

Open Burning and Single Chambered Incinerators

Los Angeles data⁽⁹⁾ indicates that the combustion which takes place in a single chambered incinerator produces considerable air pollutants, and furthermore, that open burning is potentially an even greater source of contaminants.^(3,10) In Los Angeles, where air pollution is an acute problem, the emissions resulting from the use of single chambered incinerators, and open fires, were so great that the authorities deemed it necessary to ban both disposal methods. Hamming states that the ban resulted in the following benefits:⁽¹¹⁾

- (a) greatly reduced the number of fires.
- (b) reduced property loss caused by fires.
- (c) brought about economy through reduction of unnecessary responses by fire apparatus.
- (d) tended to expedite the reporting of true fire alarms.
- (e) reduced the personal hazard to the lives of firemen and public through the reduction of emergency responses.
- (f) eliminates the need for incinerator inspection by fire department personnel.
- (g) it has made a cleaner community.

Table 32 demonstrates the pollutant reduction which was accomplished by the ban on single chambered incinerators and open burning in Los Angeles.

Table 32 - Emissions of Air Contaminants from Burning of Combustible Refuse in Los Angeles County (a)

Contaminant	Emissions in Tons Per Day Prior to Ban on Open Fires & Single Chamber Incinerators	Emissions in Tons Per Day After Ban on Open Fires & Single Chamber Incinerators
Hydrocarbons	35	n
Aldehydes & Keytones	55	n
Other Organic Gases	40	4
Oxides of Nitrogen	25	3
Sulfur Dioxide	20	1
Carbon Monoxide	175	4
Other Inorganic Gases	n	n
Aerosols	80	4

n - negligible, less than .5 tons/day

(a) - Los Angeles County Air Pollution Control District. Technical Progress Report, Control of Stationary Sources, April 1960.

Thus the elimination of single chambered incinerators and open burning is expected to considerably reduce the emission of contaminants to the atmosphere.

Multiple Chambered Incinerators

Studies have revealed that a properly designed multiple chambered incinerator when operated correctly can burn waste material with a minimum emission of contaminants. (13,9,10)

Design standards have been prepared for Alberta⁽¹⁴⁾, and these should ensure incineration which does not result in excessive atmospheric pollution.

Municipal Incinerators

These are generally large, specially designed multiple chambered units which are operated 24 hours per day. If properly designed, and carefully operated the air pollution potential from these units should be small.

In summary, a combination of sanitary landfill and the use of multiple chambered incinerators is considered the most practical way to reduce the air pollution potential from waste disposal. Open burning, and single chambered incinerators (including domestic incinerators) have high pollution emission potential and should, therefore, be eliminated.

Emissions in the Edmonton Area

In Edmonton some 232,000 tons of refuse and garbage are disposed of at City owned installations. Of this total 65,000 tons were disposed of by open burning, 60,000 tons were burned in a municipal incinerator, and the remainder was disposed of as landfill. The City of Edmonton Fire Marshall estimates that there are roughly 7,000 private incinerators in Edmonton. The industrial survey indicated that 40 out of 210 industries had incinerators, and that these units were used to consume about 40,450 tons of material per year. Thus, some 6,960 incinerators have not been accounted for. Data presently available indicates that roughly 400 commercial and apartment incinerators exist, and that they consume an average of 200 lbs. of waste per week.

It is estimated that one domestic incinerator burns approximately 150 lbs. of waste per month, and it is expected that there are about 6,560 of these units in Edmonton. Table 33 outlines the quantities of waste material being incinerated by various methods.

Table 33 - Amount of Material Incinerated in Edmonton

Method	Quantity Tons/Year
City of Edmonton Municipal Incinerator	60,000
City of Edmonton Open Burning	65,000
Industrial Incinerators	40,450
Estimate of Commercial Incineration	2,080
Estimate of Domestic Incineration	<u>5,904</u>
TOTAL	<u><u>173,434</u></u>

Estimates of emissions from various types of incineration practices have been made in various references. (2,3,5,6,7,13,15,16) The data which appears to be most applicable to Alberta conditions is presented in Appendix D. Emission estimates for the Edmonton area are presented in Tables 34, 35 and 36. Emissions were calculated for present conditions and under the assumption that open burning be discontinued and all single chambered incinerators be converted to multiple chambered incinerators.

Table 34 - Estimated Emissions Which Result from Incineration in Edmonton
(Excluding the Municipal Incinerator)

Compound	Emissions in Tons Per Year			
	Open Burning	Industrial	Commercial Estimate	Domestic Estimate
Methanol	292-747	182-465	9-24	27-68
Ethylene	260-1,982	162-1,234	8-63	26-180
Acetone	< 260	< 162	< 8	< 26
Methane	747-4,875	465-3,034	24-106	68-443
Acetylene	< 130-2,372	< 81-1,476	4-76	12-215
Alpha Olefins (as Propylene)	< 145	< 121	< 6	< 18
Carbonyl Sulfide	> 97	> 61	> 3	> 9
Benzene	> 97	> 61	> 3	> 9
Acids (as Acetic)	> 130	> 81	> 4	> 12
Phenols (as Phenol)	> 260	> 162	> 8	> 24
Aldehydes (as Formaldehyde)	162-2080	101-1,294	5-67	15-189
Ammonia	29-130	18-81	1-4	2-12
Oxides of Nitrogen	< 3	< 2	< .12	< .25
Carbon Monoxide	6,402-32,175	3,484-20,022	205-1,029	581-2,922
Particulate Matter	497-728	309-453	16-23	45-66

Table 35 - Summary of Estimated Emissions Which Result from Incineration in Edmonton.

Compound or Group	Municipal Incinerators	All Others	Total
Methanol	* ---	510-1304	510-1304
Ethylene	---	454-3460	454-3460
Acetone	---	< 454	< 454
Methane	---	1304-8507	1304-8507
Acetylene	---	< 227-4140	< 227-4140
Alpha Olefins	---	< 340	< 340
Benzene	---	> 170	> 170
Total Hydrocarbons ***	24	< 3459- < 18,375	< 3483- < 18,399
Carbonyl Sulfide	--- **	> 170	> 170
Acids	---	> 227	> 227
Phenols	---	> 454	> 454
Aldehydes	1	289-3630	290-3631
Ammonia	---	51-227	51-227
Oxides of Nitrogen	81	< 6	87
Carbon Monoxide	16	11,173-56,150	11,189-56,166
Particulate Matter	657	868-1270	1525-1927

* Hydrocarbons were measured as total organic content using a non-dispersive hexane sensitized infrared gas analyzer.

** Dashes indicate that no data is available.

*** Total hydrocarbons for incinerators other than municipal are the sum of the compounds above the total hydrocarbon line, i.e. methanol-benzene.

Table 36 - Emissions Expected in the Event that Incinerator Controls are Effected.

Compound	Emissions in Tons	
	Case 1	Case 2
Methanol	≤ 1.06	27-69
Ethylene	≤ 1.06	25-181
Acetone	≤ 1.06	≤ 25
Methane	≤ 1.06	69-444
Acetylene	≤ 1.06	$\leq 13-216$
Aldehydes	≤ 1.06	≤ 19
Benzene	≤ 1.06	> 10
Total Hydrocarbons	≤ 31.42	188 - 964
Carbonyl Sulfide	≤ 1.06	> 10
Acids	≤ 1.06	> 12
Phenols	≤ 1.06	> 25
Aldehydes	~ 7.32	21-145
Ammonia	≤ 1.06	4-13
Oxides of Nitrogen	~ 125	45
Carbon Monoxide	≤ 17.06	582-2923
Particulate Matter	699	92-113

Case 1 - assumes that the municipal incinerator continues operation, that all single chambered incinerators (other than domestic) are converted to multiple chambered units, and that all domestic and open incineration is eliminated.

Case 2 - assumes that open burning is discontinued, that municipal incineration is continued, that domestic incineration remain as single chambered incinerators, and that all other incinerators (commercial etc.) are converted to multiple chambered incinerators.

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16. COMBUSTION OF FUEL

The combustion of fuel for heating and process purposes can contribute large or small quantities of contaminants to the atmosphere, depending upon the fuel used. Generally, the combustion of natural gas results in the least emission whereas coal is a potential source of large quantities of pollutants. In Edmonton, natural gas is used in nearly all combustion processes. The use of coal is practically nonexistent, but, some 360,161 barrels of fuel oil were used in Edmonton in 1963, (by the City Power Plant and the Oil refineries). Table 37 presents the gas consumption figures for the City of Edmonton.

Table 37 - Consumption of Natural Gas in Edmonton in 1963

Consumer	Consumption, billions of cubic feet
Domestic - Residential	15.1
Commercial	12.0
Small Industrial	2.4
Large Industrial	20.1
TOTAL	<u>49.6</u>

Emissions

Combustion results in the emission of large quantities of carbon dioxide, nitrogen and oxygen. In addition: small amounts of sulfur oxides, nitrogen oxides, hydrogen fluoride, hydrogen sulfide, carbon monoxide, organic acids, and aldehydes are produced.

Sulfur Oxides

The amount of sulfur oxides appearing in combustion effluent gases is dependent upon the sulfur content of the fuel. Table 38 presents the average composition of Edmonton natural gas. It should be noted that although

the sulfur content is zero, a minute amount of sulfur is present in the form of mercaptan which is used for odorizing. Since local natural gas contains little sulfur, sulfur dioxide and trioxide emissions are considered to be negligible.

Table 38 - Average Characteristics of City of Edmonton
Natural Gas

O_2 - 0	C_2H_6 - 4.42
N_2 - 3.08	C_3H_8 - 2.79
CO_2 - 0.19	C_4H_{10} - 0.79
H_2S - 0	Heating Value - 1020 B.T.U./cu. ft.
CH_4 - 88.61	Specific Gravity - 0.63

Nitrogen Oxides

The various oxides of nitrogen are formed when the oxygen and nitrogen found in the atmosphere are heated to high temperatures. The amount of nitrogen oxides formed is dependent upon the temperature achieved. Slow cooling of the products of combustion usually results in the decomposition of the nitrogen oxides, however, maximum utilization of the combustion process usually required quick transfer of the heat produced. Thus, oxides of nitrogen are generally emitted from combustion processes.

Other Gaseous Contaminants

Other gaseous contaminants are generally emitted, but in smaller quantities.

Control

Generally the use of natural gas as fuel is considered to be the most effective control method. Modification of combustion equipment can reduce the emission of nitrogen oxides and sulfur trioxide. Effluent treatment is effective in reducing visible emissions but most gaseous

contaminants are present in such small concentrations that treatment methods are not presently available.

Emissions in the Edmonton Area

There are a number of data available from which emission estimates can be made (1,2,3,4,5). Unfortunately, none of these sources agree in respect to the expected emission from natural gas. Table 39 presents the emission factors used in calculating the emission of pollutants in Edmonton, Table 40 presents the emissions expected in the Edmonton area.

Table 39 - Expected Emission of Contaminants from the
Combustion of Various Fuels

Contaminant	Emission in Pounds/Pound of Fuel for Various Types of Fuel (h)				
	Natural Gas		Fuel Oil	Coal	
	Domestic	Industrial		Domestic	Industrial
SO ₂	Depends on sulfur content				
SO ₃					
Oxides of Nitrogen	.004	.005	.013	.002	.101
Aldehydes	.0006	.0004	.0018	.001 (g)	.001 (g)
Total Hydrocarbons	.0015	.0015	.005	.010	.010
Organic Acids	.0012	.0012	.015	-	-
Ammonia	.000006	.000006	.000006	-	-
Inorganic Chlorides	-	-	-	.002	.002
Fluorides	-	-	-	-	.0002 (a)
Solids	-	-	.00025	.012 (d)	.15A (b)
				.006 (e)	.75A (c)
				.027 (f)	

(a) Fluoride concentration will vary with coal composition. An approximate fluoride composition is .2% by weight.

(b) Solids emission will depend upon the ash content of the coal A. The factor .15 is applicable for underfeed stokers, travelling grate and cyclone furnace type of installation.

- (c) Applicable to pulverized coal burning.
- (d) Total particulate made up of .002 lbs./lb. of ash and .010 lbs./lb. of carbon and tars. Applicable to hand-fired furnaces.
- (e) Stoker-fired furnaces comprised of .0015 lbs./lb. of ash and .004 lbs./lb. of carbon and tars.
- (f) Coal burning stoves, comprised of .003 lbs./lb. of ash and .024 lbs./lb of carbon and tars.
- (g) Taken from: "Literature Review of Metropolitan Air Pollutant Concentration, Preparation, Sampling and Assay of Synthetic Atmosphere", Stanford Research Institute, November 1956.
- (h) "Pure Air for Pennsylvania", Pennsylvania Department of Health, and the Public Health Service, U.S. Department of Health, Education and Welfare.

Table 40 - Expected Emissions from the Combustion of Fuel
in the Edmonton Area

Contaminant	Commercial and Domestic	Industrial	
	Natural Gas	Natural Gas	Fuel Oil
Oxides of Nitrogen	2,575 tons	2,672 tons	772 tons
Hydrocarbons	966 tons	802 tons	297 tons
Organic Acids	772 tons	641 tons	891 tons
Ammonia	3.9 tons	3.2 tons	.5 ton
SO ₂	Negligible	Negligible	Negligible
SO ₃	Negligible	Negligible	Negligible
Aldehydes	366 tons	213 tons	107 tons
Solids	Negligible	Negligible	15 tons

Combustion of Coal

Alberta has rich deposits of both coal and petroleum and either could be used as an energy source. Therefore, as a matter of interest, the emissions expected if coal were used as fuel were calculated.

The Research Council of Alberta provided an estimate of the average Alberta coal properties as follows:

- 1) Specific heat - 10,000 B.T.U. per lb.
- 2) Sulfur content - .2%
- 3) Ash Content (A) - 10%

Table 41 presents the emissions expected if coal were used rather than natural gas and fuel oil. It should be noted, however, that these figures are rough estimates only, and that the emissions due to coal consumption will depend upon:

- 1) Type of combustion equipment
- 2) Condition of equipment
- 3) Firing practices

Table 41 - Atmospheric Pollutants Expected in Edmonton Using Coal or Petroleum Products (Natural gas and fuel oil) As Fuel

Contaminant	Emissions - tons	
	Petroleum Products	Coal
SO ₂	Negligible	4433
SO ₃	Negligible	498
H ₂ S	Negligible	20.7
Oxides of Nitrogen	6019	12,671
Aldehydes	686	2590
Total Hydrocarbons	2065	25,950
Inorganic Chlorides	-	5190
Solids	Negligible	34,860

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17. THE INTERNAL COMBUSTION ENGINE

Early in 1952 A. J. Haagen-Smit ⁽¹⁾ published a paper which outlined the theory of photochemical air pollution formation. Essentially the theory states that photochemical smog formation is related to the amount of organic gases and nitrogen oxides present in the air. Since oxides of nitrogen and hydrocarbons are emitted from internal combustion engines, Haagen-Smit's theory triggered a great deal of research into the contribution of exhaust gases to the formation of photochemical smog.

Emissions

Gasoline and diesel fueled engines are the principal type of internal combustion engines used today. The contaminants which are emitted as a result of their operation vary since fuel composition and operating characteristics differ. It is interesting to note that contrary to public belief diesel engines generally emit a lesser amount of pollutants per gallon of fuel than gasoline engines.

1. Gasoline Fueled Engines

Exhaust Emissions

The operation of a gasoline fueled engine involves the compression of a pre-combined mixture of air and gasoline, and its subsequent combustion in a cylinder. When the hydrogen and carbon which make up gasoline combine with oxygen, water vapor and carbon dioxide are formed. Combustion such as this is referred to as ideal, and the exhaust gases are harmless. Unfortunately ideal combustion is very difficult to achieve in gasoline engines, and improper combustion results in the emission of compounds which are the cause of the motor vehicle air pollution problem.

The most efficient combustion occurs when the engine air supply is slightly in excess of that required to completely burn the fuel. Theoretically, 15 pounds of air is required to burn one pound of gasoline,

resulting in an air-fuel ratio of 15:1, but maximum power is developed at air-fuel ratios of from 12:1 to 15:1. The motoring public expect the operating characteristics of the present day automobile to be such that the engine must be operated at air-fuel ratios less than 15:1. As a result, insufficient air is present in the cylinder to support the combustion of all the gasoline constituents, and contaminants are emitted from the exhaust system.

Further exhaust emissions result from the additives contained in gasoline. Additives are placed in gasolines to reduce engine knocking, color the gas, alter combustion chamber deposits, prevent deterioration of the fuel, prevent catalytic activity of metals present in minute quantities in gasoline, as antirust agents, anti-icing agents, and for several other reasons. These additives undergo chemical changes during the combustion process and are released to the atmosphere. Also, if the engine is badly worn partially burned or unburned lubricating oil may be emitted.

Engine exhausts are the largest engine pollutant sources, however three other sources exist. Hydrocarbon emissions result from: gasoline evaporation from the carburetor and the fuel tank, and emissions from the crankcase breather.

The emission of air contaminants from an engine at any particular moment is dependent upon the type of operation the engine is subjected to at that moment. Basically there are four driving cycles:

- 1) Cruising, i.e. the vehicle is moving at a constant speed
- 2) Acceleration, i.e. the vehicle is increasing its speed
- 3) Deceleration, i.e. the vehicle is decreasing its speed
- 4) Idle, i.e. the vehicle is standing still.

There are four major contaminants emitted as exhaust gases.

A. Hydrocarbons

The hydrocarbons released in engine exhausts are dependent on the air-fuel mixture, and manifold vacuum, which are both dependent upon engine operation and load. Table 42 demonstrates the effect which various operating cycles have upon these factors. The effect of vacuum and air-fuel ratio upon hydrocarbon emission is presumed to result from residual gas dilution and wall quenching (2). The amount of residual hydrocarbon vapors remaining in the cylinder is dependent upon intake manifold vacuum, and as fresh fuel-air mixtures are introduced into the cylinder they are mixed with the remaining hydrocarbon vapors. As intake manifold vacuum increases, so does the amount of residual gas until at manifold vacuums in excess of 21 inches of mercury, the residual gas accounts for 1/4 of the total combustion mixture in the chamber. The result is that insufficient oxygen is available for combustion and excessive hydrocarbon emissions occur. This condition occurs only during deceleration.

The effect of wall quenching upon hydrocarbon emissions is, that as the flame front in the cylinder approaches the cooler cylinder wall the combustion reaction is quenched. This results in a small layer of unburned or partially burned fuel-air mixture each time a cylinder fires. The result is the emission of fuel vapors.

Table 42 - Influence of Engine Operating Conditions on Engine Variables (a)

Operating Conditions	Engine air-fuel Ratio	Exhaust Gas Flow cfm.	Ignition Timing	Manifold Vacuum (ins. Hg)
Idle	11.0:1 - 12.5:1	6-8	Full retard	18-20
Cruise, 30-50 mph.	13.0:1 - 15.0:1	25-50	Full advance	12-18
Acceleration				
Wide open throttle	11.5:1 - 13.0:1	90-125	Moderate advance	0-8
Part throttle	12.5:1 - 14.0:1	50-90	Moderate to full advance	8-12
Deceleration	11.1:1 - 12.5:1	6-8	Partially retard	20 and above

(a) U.S. Department of Health, Education & Welfare, "Motor Vehicles, Air Pollution and Health", June 1962.

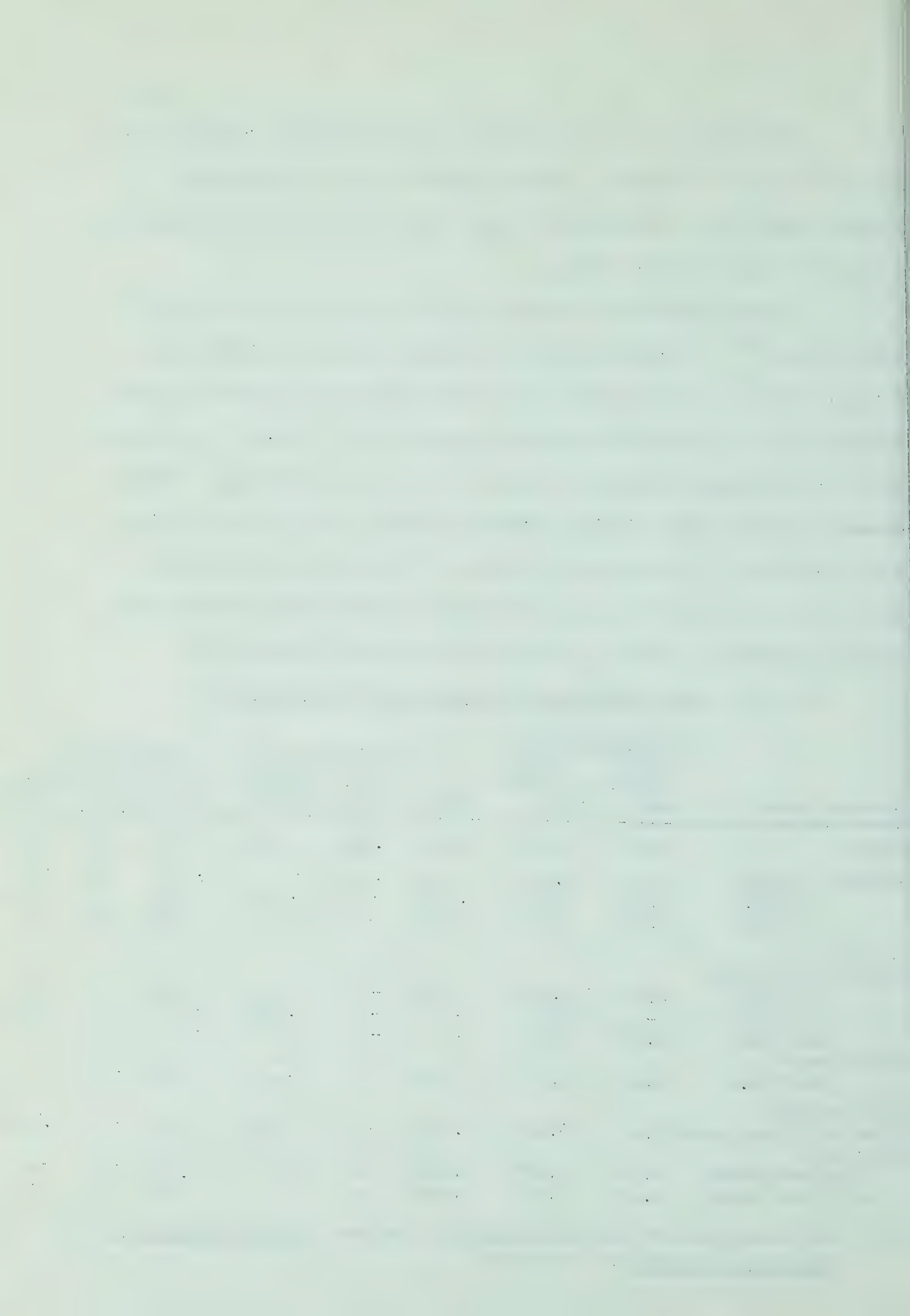
Hydrocarbon emissions are also dependent upon the air-fuel ratio, and increase as it decreases. Exhaust concentrations of hydrocarbons increase during idle, deceleration, heavy load, and road load conditions as a result of lower air-fuel ratios.

Engine maintenance, markedly affects the hydrocarbon content of exhaust gases (3). Occurrences such as cylinder misfire, or spark plug fouling result in the hydrocarbon-air mixture passing through the cylinder unburned and can increase hydrocarbon emissions $2\frac{1}{2}$ to 5 times. The increase due to fouled plugs is generally less than that due to misfiring. Table 43 presents the hydrocarbon emissions expected during various driving cycles, and is included, to demonstrate the effect of driving cycle on emission rate. The emission factors used for calculating hydrocarbon emissions from internal combustion engines in Edmonton may be found in Appendix E.

Table 43 - Automotive Exhaust Emissions of Hydrocarbons (a)

Driving Cycle	Engine Effects		Concentration, MOL Percent carbon			Weight Emission pounds per hour		
	Engine air-fuel ratio	Exhaust gas flow cfm.	Percent carbon			pounds per hour		
			Test A	Test B	Test C	Test A	Test B	Test C
Idle	11.9	6.8	1.11	0.54	0.28	0.17	0.08	0.04
Cruise: 30 mph.	13.3	24.6	.75	.30	-	.42	.17	-
40 mph.	13.6	35.6	.56	-	.13	.45	-	.11
50 mph.	13.9	48.5	.78	.26	-	.86	.29	-
Acceleration								
Wide open throttle								
0-60 mph.	12.7	125.0	.70	-	-	1.98	-	-
0-50 mph.	-	105.0	-	-	.14	-	-	.33
20-45 mph.	12.7	90.9	-	-	-	-	-	-
Part throttle								
15-30 mph.	13.3	42.4	.73	-	-	.70	-	-
Deceleration								
Free at 50 mph. start	11.9	6.8	3.60	-	1.47	.55	-	.23
Braking:								
At 40 mph. start	11.8	6.8	2.19	-	-	.34	-	-
At 30 mph. start	11.9	6.8	1.99	-	-	.31	-	-

(a) U.S. Department of Health, Education and Welfare, "Motor Vehicles, Air Pollution, and Health", June 1962.



B. Oxides of Nitrogen

Oxides of nitrogen are formed in the internal combustion engine by the combination of oxygen and nitrogen in the presence of heat. Their formation is dependent upon the availability of oxygen and the combustion temperature which are dependent upon the air-fuel ratio. Richer mixtures of air and fuel tend to produce fewer oxides of nitrogen and as the fuel mixture becomes leaner the oxides of nitrogen formed increase to a maximum at an air-fuel ratio of about 17:1. As air-fuel ratios increase above 17:1 the formation of oxides of nitrogen decreases, presumably as a result of lower combustion temperatures. The formation of nitrogen oxides has also been observed to increase with advances in ignition timing, decreases in manifold vacuum, and increases in compression ratio. The oxides of nitrogen which are expected to be emitted under various driving cycles are presented in Table 44.

C. Carbon Monoxide and Carbon Dioxide

Under ideal burning conditions, no carbon monoxide should result from the combustion process, and the emission should be entirely carbon dioxide. Thus the emission of both compounds is primarily dependent upon the air-fuel ratio, and as the air-fuel ratio increases the carbon monoxide content of the exhaust gases decreases with a corresponding increase in the carbon dioxide content. It is expected that at air-fuel ratios in excess of 15:1 the carbon monoxide concentration of the exhaust gases will be at a minimum. Table 44 presents the carbon monoxide emissions expected. It should be noted that the carbon monoxide emission is greatest during acceleration since gas flows are larger during this phase (as opposed to higher carbon monoxide content of the gas during idle and deceleration).

Table 44 - Automotive Exhaust Emissions of Oxides of Nitrogen and Carbon Monoxide (a)

Driving Cycle	Engine Effects		Oxides of Nitrogen					
	Air fuel ratio	Exhaust Gas flow cfm.	Concentration, ppm.			Weight Emission		
			Test A	Test C	Test D	Test A	Test C	Test D
Idle	11.9	6.8	30	-	-	0.001	-	-
Cruise: 30 mph.	13.3	24.6	905	-	1208	0.16	-	0.21
40 mph.	13.6	35.6	-	1465	-	-	0.37	-
50 mph.	13.9	48.5	1625	-	1273	0.56	-	0.44
Acceleration								
Wide open throttle								
0-60 mph.	12.7	125.0	-	-	-	-	-	-
0-50 mph.	-	105.0	-	506	-	-	0.38	-
20-45 mph.	12.7	90.9	1185	-	700	0.77	-	0.45
Part throttle								
15-30 mph.	13.3	42.4	1700	-	2525	0.51	-	0.76
Deceleration								
Free at 50 mph start	11.9	6.8	.60	-	-	0.003	-	-
Braking								
At 40 mph. start	11.8	6.8	-	-	-	-	-	-
At 30 mph. start	11.9	6.8	-	-	-	-	-	-

Driving Cycle	Engine Effects		Carbon Monoxide					
	Air fuel ratio	Exhaust Gas flow cfm.	Concentration mole percent			Weight Emission lbs. per hour		
			Test A	Test B	Test C	Test A	Test B	Test C
Idle	Same		6.69	6.65	6.59	1.97	1.94	1.95
Cruise: 30 mph.			3.35	1.90	-	3.57	2.03	-
40 mph.			2.51	-	1.43	3.88	-	2.22
50 mph.			1.90	1.42	-	4.00	3.00	-
Acceleration	as							
0-60 mph.			4.83	-	-	26.2	-	-
0-50 mph.			-	-	5.76	-	-	26.3
20-45 mph.			-	-	-	-	-	-
Part throttle	previous							
15-30 mph.			3.09	-	-	5.66	-	-
Deceleration								
Free at 50 mph start	tests		6.69	-	-	1.97	-	-
Braking								
At 40 mph. start			6.70	-	-	1.98		
At 30 mph. start			6.68	-	-	1.97		

(a) U.S. Department of Health, Education and Welfare, "Motor Vehicles, Air Pollution and Health", June 1962.

D. Particulates

Limited test data is available on the emission of particulates, however tests on a limited number of engines indicates that particulates in the exhaust gases amount to about 5% by weight of the hydrocarbon vapor. The particulates emitted consist of lead compounds, carbon particles, motor oil, and others. Although particulate emissions have not been extensively studied they are considered to be of a significant amount to warrant intensive investigation.

Crankcase Blowby

During the operation of the gasoline engine a certain amount of gaseous material escapes from the cylinder, past the pistons, into the crankcase. The mixture is composed of about 85% fuel-air mixture with the remainder being exhaust gases. Roughly 25-35% of the hydrocarbon emissions originate from this source. The emission rate increases as air flow increases, and is therefore worse under heavy load conditions. The mechanical condition of the engine also plays an important function in blowby emissions.

Fuel Evaporation from the Fuel Tank

Less than 4 percent of the total hydrocarbons emitted from a gasoline fueled engine are estimated to originate from the fuel tank. When fuel tanks are partially filled, hydrocarbon vapors occupy the unfilled space. The emission of these vapors depends upon the volatility of the fuel, the ambient temperature and motion of the car. It is estimated ⁽²⁾ that with high temperatures, and the vehicle in motion, the hydrocarbon emissions will approach 0.05 lbs. per hour.

Carburetor Evaporation

Modern carburetors have their float bowls vented to the atmosphere by means of an internal or external vent, or a combination of both. Either venting method results in hydrocarbon emissions during the running period. At an ambient temperature of 75°F. a loss of from 0.0002 - 0.002 pounds per hour can result, while at lower ambient temperatures losses are negligible.

A second carburetor emission results from the hot soak loss which occurs after the engine has been shut off. Hot soak losses occur when the stored engine heat warms the gasoline in the carburetor and thereby causes a portion of it to evaporate. The gasoline fumes are released to the atmosphere through the carburetor vent system. The amount of fume released depends upon the storage capacity of the carburetor, the ambient temperature, volatility of the fuel, and driving conditions prior to engine stoppage. Latest data indicate that under average driving conditions and a volatile type fuel, hot soak losses may vary from 0.0012 pounds at 60°F ambient temperature to 0.076 pounds at 95°F ambient temperature.

Estimates of emissions from gasoline fueled internal combustion engines are presented in Appendix E.

2. Diesel Fueled Engines

The diesel engine is different from the gasoline engine in that it compresses air only rather than an air-fuel mixture, it uses a heavier and therefore less volatile fuel, and the fuel autoignites. Thus combustion does not take place in a homogenous mixture but within the fuel spray as it is injected. In most cases the diesel is operated with combustion air in excess of stoichiometric requirements. In general inefficient or incomplete combustion in the diesel engine, which results in the emission of unburned material as smoke, results from poor maintenance or improper adjustment of fuel supply jets. The exhaust gas concentrations of most compounds are lower in diesel exhausts and this probably results from the greater air-fuel ratios achieved in diesels. Oxides of nitrogen concentrations in the exhaust gases during the idle and deceleration are similar for both engines, but the diesel emission of hydrocarbons and oxides of nitrogen expressed in pounds per hour are higher than those encountered for gasoline engines because of the large volume of exhaust gases. Table 45 presents the estimated emissions expected from diesel engines.

Table 45 - Exhaust Emissions From Diesel Engines

Driving Cycle	Exhaust Gas Flow	Range of Contaminants					
		Oxides of Nitrogen		Hydrocarbons		Carbon Monoxide	
		Conc. ppm.	Pounds per hr.	Conc. ppm.	Pounds per hr.	Conc. ppm.	Pounds per hr.
Idle	114	59	0.05	0.15	0.38	0	0
Cruise: 30 mph.	345	237	0.59	0.04	0.30	0	0
Acceleration: Part throttle at 15 mph.	479	849	2.90	0.07	0.68	0.05	1.04
Deceleration: Constant at 25 mph.	302	30	0.06	0.15	0.96	0	0

Several other emissions result from diesel operation. Odors are emitted and their cause has not as yet been established. Blowby results in the emission of some hydrocarbons, however the emission rate is much lower than that associated with gasoline engines. Emissions in the .011 pound per hour range are generally expected.

Control

Approximately 25 to 35% of the hydrocarbons emitted by motor vehicles are released as a result of crankcase blowby, while some 60 to 70% of the total contaminants are released as exhaust gases. As a result control of the hydrocarbons which are emitted by carburetor and fuel tank evaporation has not been actively promoted.

Crankcase Blowby

Blowby emissions consist of a mixture of hydrocarbon vapors and exhaust gases which are blown past the pistons into the crankcase. These gases are vented by means of the crankcase breather pipe and thereby released to the atmosphere. Two control systems have been developed: (1) direct vent tube, (2) variable-orifice metering.

The direct vent tube simply vents the crankcase through the carburetor or carburetor air cleaner. The system requires no valve, and therefore requires a minimum of service. Devices similar to these have been in use on European cars for many years (2).

The variable-orifice system consists of a tube connecting the crankcase with the intake manifold, in which a variable-flow metering device is installed. The metering device is designed to reduce the flow through the system during periods of high manifold vacuum (i.e. idle and deceleration) and increase the flow with increasing cruise speeds. The disadvantage of the system is that because of the low vacuum at full throttle acceleration the blowby exceeds the crankcase ventilation rate causing blowby emission (presumably through the oil filler cap). In addition to this drawback, frequent servicing of the metering device is necessary since it tends to clog.

Exhaust Emission Control

Two types of device have been studied: 1) engine operating control device and 2) exhaust control device. Engine operating devices are primarily fuel supply controls designed to reduce emissions during deceleration. Controls have included devices to positively shut off the fuel supply or to shut it off by means of an air bleed. Both devices are not considered to be very efficient. A second group of controls is designed to reduce manifold vacuum and thus increase the air-fuel ratio during periods of high manifold vacuum. Generally, these methods of control are applicable to the deceleration cycle and therefore not too efficient.

A certain amount of study has been directed towards evaluating the effectiveness of good maintenance in reducing pollution emissions. One automobile manufacturer has demonstrated that passenger cars when carefully tuned, and equipped with a spark timing control (designed to advance the spark during deceleration and retard it during idle) emit a tolerable quantity of pollutants (2).

Exhaust Control Devices

Some of the systems which have been proposed are afterburners, catalytic converters, absorbers, absorbers, filters, and condensers. Of these only the afterburner and catalytic converters are receiving serious consideration. Both are designed to treat exhaust gases during all driving cycles and therefore have an advantage over the engine operation control devices. The design and development of both systems is hampered by the following problems (2):

- 1) the concentration of the combustibles present in the exhaust stream vary over wide ranges.
- 2) the temperature of the gases varies from 150° to 1500° depending upon location.
- 3) a great deal of heat is produced by the combustion reactor.

The catalytic converter has several advantages as compared to the direct flame afterburner in that its ignition temperature is lower and it is better able to maintain the stability of the oxidizing flame. Unfortunately the catalyst in the converter may be fouled by lead compounds present in the gas, sintered or de-activated by high temperatures, or may be worn out through abrasive action. The result is a gradual decrease of effectiveness with use, and the necessity of regular replacement of the catalyst.

Emissions Expected in the Edmonton Area

The estimation of the contaminants released to the atmosphere from motor vehicles in the Edmonton area is a very difficult problem. Although there is a fair amount of information available (2,4,6,7,8) much of the data was obtained from studies conducted in the Los Angeles area. Since emissions may vary with driving conditions, ambient air temperatures,

state or repair of the engine etc., the application of Los Angeles data per sec. to Edmonton could result in gross estimating errors. In order for accurate estimates to be made a detailed study of Edmonton driving habits, types and quantities of fuel used, effects of ambient temperature, condition of engines, relative ages of vehicles, etc., and their effect upon emissions is necessary. Such a study would represent a major undertaking and was therefore beyond the scope of this study. Estimated emission factors for Edmonton motor vehicles are presented in Appendix E with an explanation of how they were arrived at.

Most vehicle emission factors are expressed in terms of pounds of contaminant per hour of operation or per gallon of fuel consumed. Automobile registrations for the greater Edmonton area including the Jasper Place district, totalled 110,427 in 1963 while other vehicle registrations were 23,357. Registrations of automobiles for various previous years for Edmonton are presented in Table 46, however those previous to 1962 are estimates only (1962 & 1963 figures were arrived at through electronic processing of registration data). Although registration figures are useful for comparative purposes they are relatively useless for emission estimates because they provide no information on city miles travelled or gasoline consumed. Although data of this nature could have been obtained by surveying a large number of vehicle owners, such a study would require a great deal of time and was considered beyond the scope of the source study.

It was felt that a more reasonable method of calculating emissions was to use an estimate of the quantity of fuel consumed in Edmonton each year. The marketing departments of various oil companies were requested to make estimates of total fuel sold in Edmonton. Each company's estimate was based on company sales, knowledge of refinery sales, traffic flows, and marketing information in regard to other companies. The estimates from each



of the firms were averaged and the results indicate Edmonton's gasoline sales to be approximately 60.625 million gallons per year, and diesel sales to be about 3.5 million gallons per year. The amount of fuel burned in the Edmonton area was assumed to be equal to sales because:

1) Vehicles which purchase fuel in Edmonton and consume it outside of the city were assumed to be nearly balanced by those vehicles which purchase fuel outside the city and burn it within the city area.

2) It was considered an impossible task to estimate fuel consumption within the city area without the use of a very extensive survey. Thus the emission estimates are at best a very rough estimate and could vary considerably from the figures presented in Table 47.

Table 46 - Motor Vehicle Registrations for Edmonton

Year	Automobiles	Other Vehicles
1963	110,427	23,357
1962	100,508	22,043 (a)
1961	89,930	20,389
1959	98,249 (total)	

(a) Figures for 1962 and previous do not include Jasper Place.

Table 47 - Expected Emissions Resulting from the Operation
of Motor Vehicles in Edmonton

Compound	Emission, tons per year		
	Gasoline Vehicles	Diesel Vehicles	Total
Carbon Monoxide	109,206	n	109,206
Oxides of Nitrogen	5,460	467	5,927
Aldehydes	182	34	216
Organic Acids	73	65	138
Solids	11	181	192
Sulfur Oxides (as SO ₂)	262	29	291
Ammonia	73	na	73
Hydrocarbons:			
Exhaust gases	14,561	1,503	
Hot soak loss	201	n	
Handling loss	779	n	
Total Hydrocarbons			17,045

n - negligible

na - not available

References

17-15

- (1) Haagen-Smit, A.J. "Chemistry and Physiology of Los Angeles Smog", Industrial Engineering Chemistry, 44, 1342-1346 (1952).
- (2) U.S. Department of Health, Education and Welfare, "Motor Vehicles, Air Pollution, and Health", June 1962.
- (3) U.S. Department of Health, Education and Welfare, "Proceedings of the National Conference on Air Pollution", December 1962.
- (4) U.S. Department of Health, Education, and Welfare, "Proceedings, of the National Conference on Air Pollution", November 1958.
- (5) Journal of the Air Pollution Control Association, June 1964, Vol. 14:241.
- (6) State of California, Department of Public Health, Technical Report of California Standards for Ambient Air Quality and Motor Vehicle Exhaust, December 1959.
- (7) Pennsylvania Department of Health and the U.S. Department of Health, Education, and Welfare, Pure Air for Pennsylvania, November 1961.
- (8) Stanford Research Institute, Literature Review of Metropolitan Air Pollution Concentrations - Preparation, Sampling and Assay of Synthetic Atmosphere, November 1956.

DISCUSSION OF RESULTS

Results of the survey have been presented in the previous sections, and will be discussed in the following pages of this report.

1. The Questionnaire

The questionnaire used in this survey was partially successful in providing the data necessary for calculating pollutant emissions. In reviewing the use of the questionnaire, several points are evident:

A. A relatively complete return is necessary for the success of a survey.

Although a certain number of non-returned questionnaires is permissible the number will depend upon the type of industries not replying. In the case of the Edmonton survey, a majority of the industries which did not reply were deemed to be of low pollution potential, and their silence did not adversely affect the survey.

B. In the event that a single questionnaire is used, it must be simple

enough to allow all industries to reply. The Edmonton survey would indicate that the data received on such a form is in many cases

incomplete. Large industries do not report in enough detail, while smaller industries tended to provide incomplete data (e.g. quantities of raw materials and finished products were often omitted). It is unlikely that a single questionnaire design is capable of completely eliminating these problems, however a multiple questionnaire survey might provide more complete data. In such a survey a separate form could be used for specific industrial classification or groups of classifications.

C. Many of the industries were rather slow in replying to the questionnaire.

In general, when telephoned, all indicated that they intended to reply.

In the event that surveys of this nature are attempted in the future, time should be allotted for personally contacting about 40% of the industries surveyed.

- D. It appeared that many industrial concerns were not aware that they emitted pollutants. It is hoped that the questionnaire and resultant report will make them more aware of this fact.
- E. The compilation of complete mailing lists is difficult. In Edmonton the individual directory was very useful, however wrong addresses were encountered, and several industries which had discontinued operations were listed. There is also a good possibility that certain of the industries existing in Edmonton were not contacted.

Indications are that the larger industries, and hence, larger more important sources, were all contacted; and that those industries which were missed were relatively minor pollutant sources. Future work could verify this premise.

- F. Return rates indicate that it is unreasonable to expect a return in excess of 80% without personal contact.

In summary, all of the industries in the Edmonton area were very co-operative in replying to the survey, and should be commended. None refused to supply data, although a few appeared reluctant to provide quantitative data. Future surveys, if conducted, should utilize a separate questionnaire for each industrial classification, and should provide ample time for personal contact of the slow replying industries.

2. Estimates of Total Emissions in the Edmonton Area

Two hundred and ten specific sources were contacted, and most of them provided data which was used to calculate emission rates. The survey attempted to contact all of the pollutant sources in Edmonton, however it is conceivable that certain industries may have been missed. It is theorized however, that those industries which were not included in the survey were smaller and therefore relatively less important as sources of pollutants. The emission data are therefore expected to present a close

estimate of actual conditions in Edmonton. Appendix F presents a summary of the emissions expected in the city, while Table 48 presents the total emissions of the major contaminants. A comparison of emissions in several other areas is presented in Table 49.

Table 48 - Process and Fuel Burning Emissions Expected in the Edmonton Area in Tons/Year

Compound	S o u r c e						
	Fuel Burning					Process	
	Heating	Incineration	Motor Vehicle	Total	% of All Emissions	Total	% of All Emissions
Total Hydrocarbons	2065	18,399	17,045	37,509	42.4	50,730	57.6
Sulfur Dioxide	n	na	291	291	6.1	4,558	93.9
Particulate Matter	n	1927	192	2119	19.6	8,693	80.4
Carbon Monoxide	n	56,166	109,206	165,372	72.4	63,227	27.6
Oxides of Nitrogen (as NO ₂)	6019	87	5,927	12,033	87.4	1,728	12.6
Aldehydes (as formaldehyde)	686	3,631	216	4,533	98.3	83	1.7
Ammonia	7.6	227	73	308	25.0	927	75.0
Other Organics	na	na	na	na	na	1742	100
Acetylene	na	na	na	na	na	2	100
Phenol	na	454	na	na	99.6	2	0.4

n - negligible

na - not available

Table 49 - Estimated Emissions of Major Contaminants (tons/day)

Compound	Edmonton	Los Angeles ⁽²⁾ County	Pittsburgh ⁽³⁾	Winnipeg ⁽⁴⁾	Philadelphia ⁽⁵⁾
Hydrocarbons	242 (1)	1767	262	170	721
Sulfur Dioxide	19	529	120	99	667
Particulate Matter	30	125	101	225	85
Carbon Monoxide	791	9841	na	na	na
Oxides of Nitrogen	42	746	62.6	54	271
Aldehydes	13	67	3.9	3.8	22
Ammonia	3	na	.6	na	1
Other Organics	5	146	na	23	123
Acetylene	n	na	na	na	na
Phenol	1	na	na	na	na
POPULATION	350,000	4,900,000	1,600,000	na	1,900,000
AREA	85.4	1500	730	260	127

n - negligible

na - not available

(1) The hydrocarbon emissions calculated for Edmonton do not include emissions from the use of organic solvents.

(2) "Technical Progress Report, Control of Stationary Sources Volume 1", Air Pollution Control District, County of Los Angeles, April 1960.

(3)(5) "Pure Air for Pennsylvania", Pennsylvania Department of Health and the U.S. Public Health Service.

(4) "Inventory of Air Pollution Emissions, Greater Winnipeg Area", Manitoba Department of Health, Environmental Health Laboratory.

The data presented in Table 49 indicate that the emissions expected in Edmonton generally are lower than those expected in other cities. This is especially true of sulfur dioxide, particulate matter, and oxides of nitrogen. Unfortunately comparative data is not available for cities approximately equal in size to Edmonton.

Studies in Pennsylvania (8) indicate that pollutant emissions vary in proportion with city size. It is expected that a straight line relationship exists between population and the emissions resulting from fuel burning. The relationship between population and industrial activity is also expected to approximate a straight line, however the type of industrial activity will influence the relationship between population and industrial emissions. Table 50 presents a comparison of emission rates standardized in respect to population and city area. The analysis assumes a straight line relationship between pollutant emissions and population, or city area. The data indicate that the emissions presently occurring in Edmonton are high in relationship to city size.

Therefore, if industrial emissions increase in direct proportion to the city's population, and area, undesirable pollution conditions will occur in Edmonton when the city is of a much smaller size than experience in other areas would indicate.

Table 50 - Comparison of Estimated Pollutant Emissions Per Million of City Population and Per Square Mile.

Compound	Expected Emission Per Million of Population			
	Edmonton	Los Angeles	Pittsburgh	Philadelphia
Hydrocarbons	691	361	164	379
Sulfur Dioxide	54	108	75	351
Particulate Matter	86	26	63	45
Carbon Monoxide	2260	2008	na	na
Oxides of Nitrogen	120	152	39	143
Aldehydes	37	14	2	12
Ammonia	9	na	.3	.5
Other Organics	14	30	na	65
Acetylene	n	na	na	na
Phenol	3	na	na	na

Compound	Expected Emission Per Square Mile			
	Edmonton	Los Angeles	Pittsburgh	Philadelphia
Hydrocarbons	2.8	1.2	.36	5.7
Sulfur Dioxide	.22	.35	.16	5.2
Particulate Matter	.35	.08	.14	.66
Carbon Monoxide	9.2	6.6	na	na
Oxides of Nitrogen	.49	.50	.09	2.1
Aldehydes	.15	.04	n	.17
Ammonia	.03	na	n	n
Other Organics	.06	.10	na	.97
Acetylene	n	na	na	na
Phenol	.01	na	na	na

A method of calculating the ground level concentrations expected to result from various pollutant release has been developed (8). The method is presented in Appendix G, and calculated concentrations are presented in Table 51. In calculating the ground level concentration the following assumptions were made:

- 1) Worst conditions would occur during inversion (on an area basis).
- 2) Inversion ceilings of 500 feet are common in Edmonton.
- 3) Wind velocities of 5 mph. are associated with inversions.
- 4) The City of Edmonton can be represented by a square roughly 10 miles by 10 miles.

The assumption in regard to inversion ceilings and wind velocities during inversions were based on records developed by by-daily radiosonde readings in Edmonton (9).

Table 51 - Estimated Ground Level Concentration of Pollutants at Edmonton for Various Inversion Conditions.

Inversion Period	Sulfur Dioxide ppm.	Carbon Monoxide ppm.	Hydrocarbons (as Hexane) ppm.	Oxides of Nitrogen ppm.	Particulate matter (micrograms per cu. meter)
1 hour	0.0079	0.759	0.075	0.020	29.68
4 hours	0.0175	1.688	0.167	0.054	65.88
8 hours	0.0199	1.921	0.190	0.061	74.80

The state of California have established air quality standards for these compounds as follows: (10)

a) Sulfur dioxide

Adverse level - 1 ppm. for 1 hour

Serious level - 0.3 ppm. for 8 hours

b) Carbon monoxide

Adverse level - not applicable

Serious level - 30 ppm. for 8 hours

120 ppm. for 1 hour

c) Hydrocarbons - "From the public health standpoint, the

concentration of those hydrocarbons which react photochemically should be maintained at or below the level associated with the oxidant index defined in the adverse standard". The writer interprets this remark to mean that hydrocarbon concentrations should be maintained below the adverse oxidant index level which is .15 ppm.

d) Nitrogen Oxides

Serious level - 3 ppm. for repeated daily exposures
(suggested)

e) Particulates - sufficient to reduce visibility to less

than 3 miles.

The data indicate that most contaminants are well below

accepted standards, however hydrocarbon concentrations under longer inversion conditions reach levels which are considered "adverse" (A).

An attempt at predicting the maximum permissible emission of contaminants was made and the results were:

a) Sulfur dioxide - adverse level

1 hour basis - 2400 tons per day

8 hour basis - 290 tons per day

b) Carbon monoxide - serious level

1 hour basis - 125,000 tons per day

8 hour basis - 12,300 tons per day

c) Nitrogen oxides - serious level

8 hour basis - 2,065 tons per day

(a) Adverse level is defined as "the level at which there will be sensory irritation, damage to vegetation, reduction of visibility or similar effects".

The significance of the previous calculations is difficult to assess since most pollutants emitted to the atmosphere are photochemically reacted upon, and different compounds are formed. Generally, the molecules or atoms of various compounds absorb light energy and form intermediate products such as ozone or free radicals. Subsequent reactions occur with other substances present in the air to form a secondary intermediate product such as sulfuric or nitric acid. These products are reacted upon and the result is the formation of stable end products, generally salts, (which eventually are added to the earth's soil), carbon dioxide, or water vapor. The reactions involved have been explained in several references (11), and are too detailed to discuss in this report.

In the case of the Los Angeles smog, a chain reaction is initiated whereby free radicals and peroxides are removed from the reacting compound. Nitrogen dioxide has been found to be the light sensitizer; while research has demonstrated that ozone, which accounts for the rubber cracking associated with smog is formed by the photochemical oxidation of hydrocarbons in the presence of nitrogen dioxide (12). Later research demonstrated that eye irritation does not depend solely on the amount of either hydrocarbon or oxides of nitrogen but is related to the ratio of the two (13).

In general a great deal of uncertainty exists in regard to the cause of the unpleasant effects associated with smog (e.g. - eye irritation). However, the role of nitrogen oxides in photochemically dissociating to provide oxygen atoms and ozone which subsequently reacts with the hydrocarbons is relatively clear. Other compounds have been demonstrated to be capable of photodissociation and some are:

- a) aldehydes
- b) ketones
- c) acyl
- d) peroxyacyl nitrates
- e) hydrogen peroxide
- f) and others

Thus contaminants present in the atmosphere are subjected to a variety of chemical attacks. The original compound is chemically altered to form intermediate products, some of which apparently cause the undesirable effects associated with smog. Oxides of nitrogen, hydrocarbons, aldehydes, and other substances are all capable of entering into photochemical reactions but there is no known method of predicting the effect of various emissions. Therefore estimations of control requirements in regard to compounds which are photochemically active must be determined by observation of actual atmospheric conditions. The State of California ⁽¹⁰⁾ has established an oxidant index of .15 ppm. for 1 hour as an adverse level. Concentrations nearing this level should be considered as a distinct signal that control is necessary. A limited number of oxidant readings have been taken in Edmonton, however the data is insufficient to indicate whether smog conditions are being approached. Personal observations would indicate that a light smog (detected by odor only), has occurred in Edmonton on several occasions. It is essential that these observations be validated by atmospheric monitoring.

Summary:

The total emission estimates for Edmonton indicate that in general the quantities of specific pollutants are not at a level at which they can be considered a problem. Calculation of ground level concentrations indicate that hydrocarbon emissions may be sufficient to cause atmospheric pollution problems, however several assumptions were made which should be subjected to further study. A limited amount of information is available on the occurrence and type of inversions experienced in Edmonton. Additional inversion data is necessary in order that the effect of hydrocarbon emissions can be more completely evaluated. This will necessitate the use of a tower and temperature sensing equipment. Furthermore the photochemical

activity of the hydrocarbons has not been investigated in Edmonton and should be proceeded with as soon as possible. In order to accomplish photochemical evaluation a complete set of oxidant observations are considered necessary.

Although the total emission of most contaminants in Edmonton is low by air pollution standards the emission rates are considered high for a city of this size. If industrial activity and population continue their accelerated growth, atmospheric pollution problems are foreseen in the future. The preponderance of the petroleum, petrochemical, and related industries in Edmonton which emit large quantities of organic compounds further accentuates the problem. Therefore from an area standpoint it is advantageous to begin to consider control activities now, especially in reference to hydrocarbons, rather than wait until severe atmospheric pollution forces crash control programmes.

3. PETROLEUM AND PETROCHEMICAL DEVELOPMENT, PROCESSING AND MARKETING

Estimates of emissions and their contribution to total emissions are presented in Table 52. The data demonstrate that this industrial group are major contributors of hydrocarbons and sulfur dioxide. The emission of odorous materials such as hydrogen sulfide and mercaptans have not been catalogued because of their relatively small quantities. It is very likely, however, that odorous materials are emitted by this industrial classification, and these emissions should be evaluated by the use of source sampling studies.

Table 52 - Emissions Expected from the Petroleum and Petrochemical Industry

Compound	Emission tons/year	Percent of Total Emissions
Total Hydrocarbons	50,730	57.3
Sulfur Dioxide	2,969	61.2
Particulate Matter	1.074	9.9
Carbon Monoxide	63,227	27.6
Oxides of Nitrogen (as NO ₂)	1,728	11.1
Aldehydes	79	1.7
Other Organics	1,741	-

The total emission of sulfur dioxide in the Edmonton area is considered low. The predominant use of low sulfur fuels should aid in maintaining low sulfur dioxide emissions in the foreseeable future. As a result control of sulfur dioxide emissions is not considered necessary in the foreseeable future.

Total hydrocarbon releases to the atmosphere are estimated to be at a level which may require control. Verification of this assumption by the use of ozone observations and continuous inversion observations has been

suggested. Since this industrial classification releases over 50% of the total hydrocarbon emissions, it is only logical that this group, when control is necessitated, reduce the quantity of hydrocarbons released. Within this classification, one industry releases approximately half of the group's hydrocarbon emission. It is conceivable therefore that control measures at one location could provide sufficient reduction to eliminate the need for further control. Although the decision in regard to control requirements cannot be made until monitoring of the ambient air has proceeded, preparation can be begun immediately. Source sampling, hydrocarbon surveys should be started as soon as possible at individual locations, and evaluation of available control measures should be carried out. Joint studies are considered the most effective tool in this regard.

Odorous material released by this industrial classification undoubtedly causes localized nuisance problems at downwind locations. Since many of the industries are located east of the city the problem may not be severe because of prevailing winds. A limited amount of control, i.e. the more obnoxious sources, is recommended to alleviate local problems resulting from the presence of odorous material. As in the case of hydrocarbons, source sampling surveys are necessary to locate sources and to isolate the compounds causing the odors. Both studies could easily be combined and should receive top priority.

Summary

Total emission data indicate that hydrocarbon control may be necessary at this time, but further evaluation in the form of atmospheric monitoring is required to verify this assumption. During the time that atmospheric evaluation is being carried out, source studies are recommended to positively establish hydrocarbon, and odorous material emissions. Control of major odor sources is recommended because of their contribution to localized problems.

4. INDUSTRIAL CHEMICAL MANUFACTURING, PROCESSING AND MARKETING

Table 53 presents the emissions expected from this classification and their contribution to the total emission expected in Edmonton. Because of the diversification of processes in this section certain emissions may not have been estimated, however their volume is expected to be small. Source sampling studies are recommended in the future in order that historical data can be accumulated. The major emission catalogued for this group is ammonia, and the quantity involved coupled with the source location, and pollution importance of ammonia, indicates minor importance. There is of course, the possibility of odorous material emission, however most of the sources are located in such a manner that no problems should be encountered.

Table 53 - Emissions Expected from the Industrial
Chemical Industry

Compound	Emissions tons/year	Percent of Total Emissions
Sulfur Dioxide	1589	32.8
Particulate Matter	356	3.3
Aldehydes	4	.1
Ammonia	710	57.4
Acetylene	2	-
Phenol	2	.4

5. FOOD PROCESSING

Approximately 205 tons per year or 1.8% of the total particulate matter emitted to the Edmonton atmosphere originates from this industry. Most of the particulate matter results from grain processing. Dust emitted from grain processing operations has been associated with bronchial asthma attacks and could therefore cause severe local problems. As a result the presence and location of receptors will determine whether control is necessary rather than emission levels. In the future care should be taken in locating grain processing plants to ensure that they are relatively isolated from pollutant receptors. Present installations are nearly all equipped with some form of control and do not appear to warrant any attention.

Odors are the major problem associated with this industry. Control is difficult, however some improvement could be effected with altered operating procedures, and good housekeeping. A continued co-operative programme would be useful in keeping industrial personnel aware of the problem odor cause, and in eliminating sources.

6. INEDIBLE ANIMAL AND VEGETABLE BY-PRODUCT PROCESSING

This industrial classification is probably one of the worst odor emitters in Edmonton (judging by citizen complaints). Although control is often difficult, and costly, it is considered essential. All cookers should be equipped with control devices, good housekeeping should be encouraged, and raw material storage should be discouraged during warmer months. Some improvement may result from better scheduling and this aspect of control should be investigated. Again co-operative studies will prove useful in gaining industrial co-operation and eliminating odor sources.

8. PLASTIC, RUBBER, AND RESIN PROCESSING

There is very little historical datum available in reference to this classification. Possibly this is due to the fact that the industry is relatively new, and the raw materials used are constantly changing. Edmonton appears to be slated for a large development of the plastic industry because of the abundance of raw materials (supplied by primary industries). Therefore it is essential that historical data be accumulated as soon as possible. Control requirements will depend upon the materials emitted, and as a result will have to be decided upon after source sampling has been carried out. Odors are expected to be the cause of a majority of the problems associated with this industry and control methods are available. Future industrial development should be located well away from residential areas.

9. METAL MELTING AND RECLAIMING

The principal emission from this classification is particulate matter. Some 1,546 tons per year of particulate matter is emitted or 14.3% of the total emission. Total particulate matter emitted in Edmonton is not considered to constitute an area problem, however, local problems could result from fume emission. The use of certain materials as slag results in the emission of deleterious substances and may accentuate local problems. Therefore it is recommended that the use of those slags which are known to produce noxious materials be prohibited. Where fume emissions cause local problems, control is recommended, however this will be determined by the location of receptors.

There is a possibility that the metal oxides emitted from this source could participate in atmospheric photochemical reactions. The catalytic effect of metallic oxide dusts is well known, and it has been postulated that the particles are capable of decomposing ozone which is considered a desirable effect; however the oxidization of organic material may be accelerated which is undesirable. At the present time insufficient data is available to permit definite conclusions to be formed.

10. SURFACE FINISHING AND COATING

The emission of contaminants from this group is expected to be negligible. Some odors may result from baking operations, however these are easily controlled, and do not appear to constitute a problem. As more exotic synthetic coatings are used odor problems may increase to a point where control is necessary.

Galvanizing has a relatively high pollution potential, however the amount carried out in Edmonton is minor and therefore emissions are minor.

Acetic mists may result from plating operations but are expected to create industrial hygiene problems rather than atmospheric pollution.

11. MINERAL PROCESSING

The mineral processing industry is the principal source of particulate matter in Edmonton. An estimated 5,206 tons of material are emitted each year which amounts to 48.1% of total emissions. The emissions originate from three sources: asphalt paving plants, cement manufacture, and concrete and concrete products manufacture.

Asphalt Plants

Asphaltic concrete plants generally emit large quantities of particulate matter at ground level and thereby create severe local problems. Type of fuel used has some bearing upon the emission rate so the use of natural gas should be encouraged. Because of the severity of local problems associated with these operations control is recommended. Sufficient data has been developed by the Division to indicate that those units not equipped with secondary cleaning devices emit particulates in excess of Provincial Board of Health Regulations, however the effect of various operating procedures at specific units should be evaluated before control requirements are considered.

Concrete and Concrete Products

Cement dust is released to the atmosphere as a result of these operations, and many of the processors are unaware of this fact. Since control of emissions results in the saving of useful product, co-operation of the industry should be easily obtained. Careful handling of cement is expected to reduce emissions by 300 tons per year in Edmonton. Specific recommendations can be formulated as each operation is reviewed, and it is recommended that surveys of handling methods be commenced as soon as possible.

Cement Manufacture

These processors contribute the bulk of the particulate matter expected to originate from the mineral processing industry. Although electric precipitators are used as collection devices difficulties inherent to their operation cause the emission of large quantities of material. The data indicate that particulate matter is not emitted in great enough quantities to cause area problems, however, localized problems may exist. Improved control in the form of better precipitator performance or additional equipment should effectively eliminate any local problems which might exist. In the event that new industries locate in Edmonton, or present facilities are expanded, the use of baghouse filters as control devices should be carefully investigated as they are a more preferable control method.

12. WOODWORKING AND FURNITURE MANUFACTURE

The emissions originating from this classification result principally from the incineration of wood waste. Approximately 39,000 tons per year of wood waste are burned in tepee burners which are extremely inefficient. The operation of these burners results in gross localized problems due to the emission of cinders, fly ash and unburned material, and to the area problem since large quantities of organic materials are released to the atmosphere. Studies in California have indicated that it is impossible to operate these units in such a manner that Alberta emission standards can consistently be complied with. It is therefore recommended that the use of tepee burners in Edmonton can be eliminated.

A small amount of particulate matter emitted from planing mills exists, however emission potential is considered small. Hydrocarbon emissions result from the use of paints, etc., and should be investigated.

13. COMMERCIAL ACTIVITIES

The survey indicated that the emission potential of this industry was very low with the exception of hydrocarbons. Dry cleaning plants fall within this classification and their operation is expected to result in substantial emission of hydrocarbon. Studies should be instigated in the near future to determine the hydrocarbon emission resulting from commercial activities.

14. VEHICLE MANUFACTURE AND SERVICING FACILITIES

There are few industries in Edmonton which fall within this classification. Emission expected would include a small amount of hydrocarbon and iron oxide dust (from welding operations). The quantities involved do not warrant control.

15. METAL FABRICATING

Few emissions are expected from this classification, although hydrocarbon emissions resulting from painting may be significant. Control is not necessary but useful data would be provided if the hydrocarbon emissions were evaluated.

16. TEXTILE, FABRIC, FIBER, MONOFILAMENT MANUFACTURE AND PROCESSING

Some 306 tons per year or 2.8% of the total emission of particulate matter is expected to originate from this classification. The quantity emitted does not necessitate control. A certain amount of odorous material is emitted from paper making processes, however the process utilized in Edmonton minimizes the problem.

17. DISPOSAL OF GARBAGE AND REFUSE

The disposal of waste material by incineration is expected to result in the emission of pollutants as demonstrated in Table 54. The rate of emission of hydrocarbons, particulates, carbon monoxide, aldehydes, and phenolic compounds from this activity form a significant portion of the total in the Edmonton area.

Table 54 - Emissions Expected to Result from Incineration in Edmonton

Compound	Emission in tons per year	Percent of Total Emission
Hydrocarbons	18,399	20.8
Sulfur Dioxide	not available	
Particulates	1,927	17.8
Carbon Monoxide	56,166	24.6
Oxides of Nitrogen	87	.6
Aldehydes	3,631	77.3
Ammonia	227	18.3
Phenol	454	99.6

The evaluation of total emissions in the Edmonton area has indicated that the control of hydrocarbons and other compounds which participate in photochemical reactions is necessary. Incineration results in substantial emissions of hydrocarbons, and aldehydes, and both compounds are known to participate in photochemical reactions.

It has been demonstrated in a previous section that incineration control measures such as the elimination of open burning and the use of multiple chambered incinerators are capable of reducing most pollutant emissions by 99%. The principal exception is nitrogen oxide which is expected to increase slightly. The effect which total control of incineration would have upon Edmonton emissions is demonstrated in Table 55.

Table 55 - Estimated Effect of Incineration Control Upon
Total Edmonton Emissions

Compound	Present Level	Reduction in the Event of Incinerator Control (a)	% Reduction
Hydrocarbons	88,472	18,368	20.7
Sulfur Dioxide	4,849	not available	
Particulates	10,812	1,228	11.3
Carbon Monoxide	228,599	56,149	24.6
Oxides of Nitrogen	15,489	increase of 38	neg. increase
Aldehydes	4,697	3,624	77.1
Ammonia	1,236	226	18.2
Phenol	456	453	99.3

(a) Assumes continued use of the municipal incinerator, elimination of open burning and domestic incineration and conversion of commercial and industrial incinerators to multiple chambered units.

Thus, control of incineration in Edmonton could result in a substantial reduction in contaminant emission.

There are four areas of incineration control applicable to the Edmonton case.

1. Open burning

Open burning is one of the most inefficient combustion methods available for burning waste material. In Edmonton the largest single amount or 37% of the material incinerated is open burned. The result is the emission of significant quantity of pollutants, which contribute greatly to localized and area air pollution problems. It is therefore recommended that open burning be eliminated as soon as possible. Two alternative methods of waste disposal are suggested: the use of municipal incinerators or sanitary landfill. Estimates of the cost of municipal incinerators range from 2500 to 5000 dollars per ton capacity while operating costs are estimated to

range from \$1.50 to \$4.50 per ton (14,15). The cost of landfill has been estimated by Bowermon (15) to be \$1,000 per ton capital cost, and operating costs of one dollar per ton. Therefore if land is available, landfill is the more logical economically and from an air pollution point of view.

2. Municipal Incineration

Municipal incinerators are generally well designed units of large capacity. Emissions expected to result from their operation are generally expected to be far smaller than those expected from open burning or single chambered incinerators. In Edmonton some 60,000 tons or 34% of the refuse incinerated is burned in the municipal incinerator. The principal emission expected from municipal incinerators is particulate matter and it is reported that the volume of underfire air has some bearing on the quantity emitted (16). Certain other operational practices have some bearing on emission rates and it is recommended that studies be carried out to ensure that the operation of the Edmonton units is done in such a manner that pollutant emissions are minimized.

3. Commercial and Industrial Single Chambered Incinerators

An estimated 48,000 tons of refuse is consumed yearly in approximately 500 single chambered incinerators. These units are scattered all over the city, are of a wide variety of design and have one thing in common - a high emission potential. The use of incinerators is expected to grow as the city grows and therefore the problem associated with these units is an ever-increasing one. Multiple chambered incinerators are available which are capable of reducing the emission of most contaminants by 99 percent. The principal exception is nitrogen oxides which is expected to increase slightly. Thus the problem to be resolved is not how to control incinerators but when. It is recommended that control be instigated immediately for the following reasons:

(A) As more and more incinerators are installed, the location scatter effect makes control of existing units increasingly difficult. The number of units requiring investigation at the present time are such that control will require a considerable effort, and each additional unit merely increases the problem.

(B) There is no doubt in the writer's mind that incineration is a principal source of pollutants and as such will require control, if not now, at some time in the future. Therefore it seems pointless to allow the installation of units now which will be condemned in the future.

(C) Cost of control is estimated as follows: The average cost of a single chambered incinerator ranges from \$200 to \$350 depending upon size while a multiple chambered unit costs from \$480 to \$850 depending upon size. Incremental costs vary therefore from \$280 to \$500. Assuming that 500 units are replaced at \$850, a total cost of \$425,000 results. Hydrocarbon emission reduction is expected to be approximately 6,553 tons. The petroleum industry on the other hand could reduce hydrocarbon emissions by approximately 11,000 tons per year by investing some 5 million dollars. Thus incineration control would reduce hydrocarbon emissions at a cost of 64.8 dollars per ton of reduction while the petroleum industry could accomplish reductions of the same magnitude at a cost of 454.5 dollars per ton. A similar trend is expected to result in regard to control by other industrial groups. Thus, incineration control appears to be the most economical control method available.

(D) Experience in other areas indicates that once incinerators have been installed owners are extremely reluctant to alter them in any manner. As a result every single chambered incinerator installed now represents a difficult future control problem.

4. Domestic Single Chambered Incinerators

Domestic units are in many cases small, unlined, poorly operated, and poorly maintained. Although most of them are gas fired combustion is inefficient since retention time is low. Emissions in Edmonton are low because relatively few of these units exist. As the population of the city increases so will the number of units. As a result it is expected that at some time in the distant future control of these installations will be required. At that time there may well be some 15 to 50 thousand units in existence and control may present insurmountable difficulties. It is proposed therefore that future installations be prohibited and that presently existing units be allowed to die a slow death.

Summary

Incineration is responsible for a significant portion of the pollutants emitted to the atmosphere. Control methods are available which are capable of great reductions in emissions in a relatively economical manner. As a result the following steps are recommended:

(A) Open burning should be discontinued immediately or as soon as possible.

(B) The installation of single chambered incinerators should be prohibited immediately. Proposed incinerator design standards have been prepared and these should be adopted as minimum acceptable standards.

(C) Existing commercial, and industrial single-chambered incinerators should be required to conform to minimum design standards by August 30, 1966. (In effect, all single chambered units will have to be converted to multiple chambered units, and the use of flue-fed incinerators must be discontinued.)

(D) The installation of domestic incinerators should be banned while existing units may operate unaltered.

(E) Studies should be initiated to ensure efficient operation of the municipal incinerator.

18. COMBUSTION OF FUEL

It is estimated that a large majority of the fuel consumed in Edmonton is natural gas. The emissions resulting from this activity are tabulated in Table 56. It is generally accepted that natural gas is the least offensive fuel from an air pollution viewpoint. For comparative purposes the effect of the use of coal as a fuel on total pollutant emissions was calculated and is presented in Table 57. The data demonstrate that the use of natural gas in Edmonton eliminates the emission of large quantities of solids, hydrocarbons, aldehydes, and sulfur compounds.

Table 56 - Estimated Pollutant Emissions Resulting from the
Combustion of Fuel in Edmonton

Compound	Emission - tons per year	Percent of Total Emissions
Hydrocarbons	2065	2.8
Sulfur Dioxide	negligible	
Particulates	negligible	
Oxides of Nitrogen	6019	43.7
Aldehydes	686	14.8
Ammonia	7.6	.7

Table 57 - Expected Effect of the Use of Coal as a Fuel on
Pollutant Emissions in Edmonton

Compound	Increase or Decrease in Emissions	
	Tons per year	Percent
Hydrocarbons	+ 23,885	27.0
Sulfur Oxides	+ 4,931	101.6
Oxides of Nitrogen	+ 6,652	48.3
Aldehydes	+ 1,904	41.2
Solids	+ 34,860	322.4

Since natural gas is the optimum fuel from an air pollution viewpoint, no control measures are proposed for this activity.

19. THE INTERNAL COMBUSTION ENGINE

The operation of the internal combustion engine in Edmonton contributes pollutants to the atmosphere as estimated in Table 58. Major emissions are hydrocarbons, carbon monoxide, and oxides of nitrogen.

Table 58 - Emissions Expected To Result From The Operation
of Internal Combustion Engines in Edmonton

Compound	Emissions Expected	
	Tons/Year	% Of Total
Hydrocarbons	17,045	19.0
Sulfur Dioxide	291	6.0
Particulates	192	1.8
Carbon monoxide	109,206	47.8
Oxides of Nitrogen	5,927	38.3
Aldehydes	216	4.6
Ammonia	73	5.5

Control of the emissions from this source are of two types: exhaust devices, and crankcase devices.

In discussing the control devices which are presently being considered for motor vehicles it is necessary to review the happenings in the State of California since they are the leaders in motor vehicle emission control.

During the 1950's it became apparent that motor vehicle emissions were creating a serious atmospheric pollution problem in Los Angeles (17). The State Legislature recognizing this fact in 1959, requested the Health Department to prepare a set of motor vehicle emission standards. The standards for exhaust emissions were adopted early in 1960, and required that the emission of hydrocarbon in exhaust gases be limited to 275 parts per million by volume, and that the emission of carbon monoxide be limited to 1.5% by volume of the total exhaust gas. In April 1960 the Legislature

created a State Motor Vehicle Pollution Control Board, and authorized it to approve exhaust emission control devices and require the installation of control devices on vehicles. The Board of Health later (December 1960) adopted a crankcase hydrocarbon emission rate of 0.15 percent by weight of the fuel supplied (18) .

Thus a system of approving control devices was established, and performance standards for the devices were set. In September 1961 the Board approved one crankcase emission control device, while four more were approved in April of 1962. As of April 11, 1962 the Board had preliminary screened 11 of 31 exhaust devices and they were in various stages of the required test programme. Early in the summer of 1964 the Board announced that two devices had been approved.

During the late 1950's the American automotive industry had been actively considering the problem and late in 1959 announced that all 1961 model cars sold in California would be equipped with crankcase control devices. In 1961 the industry announced that by 1963 all motor vehicles sold in the United States would be equipped with the devices. In June of 1964 the State Motor Vehicle Pollution Control Board announced that some 2½ million new cars and 400,000 used cars had been equipped with crankcase devices resulting in a 100 ton per day decrease in hydrocarbon emission in the State (19) .

The action of the United States automotive industry in reference to crankcase devices was followed by their Canadian counterparts, and control devices were installed on a majority of Canadian manufactured cars. A recent announcement by the auto industry (20) indicates that they have developed exhaust controls capable of meeting California standards. To date there has been no announcement as to whether these devices will be placed on Canadian cars, however past experience indicates that such

action is to be expected. If this is so, all new motor vehicles will very likely be equipped with devices which are capable of reducing hydrocarbon emissions by 90 percent. Most of the new cars sold in California are expected to be so equipped by 1966, and it is expected that all United States motor vehicles (and presumably Canadian manufactured motor vehicles) will be equipped at that time or within two years. The result will be a sharp reduction in the increase in motor vehicle emissions starting with the year the devices are introduced.

Used cars will remain a problem, but the devices approved in California will be applicable to this source. Until the Canadian motor vehicle industry indicates its intentions, it is difficult to quantitatively evaluate the control requirements necessary in Alberta. It is estimated, however, that if all new vehicles are equipped with devices, reductions in emissions from other sources will eliminate the need for control in used cars. This, of course, could be altered if other Canadian Provinces require used car control and a flood of used cars arrives on the Alberta market. It is therefore proposed that auto exhaust control be held in abeyance until the Canadian automotive industry announces its intentions.

CONCLUSIONS AND RECOMMENDATIONS:

Sources of atmospheric pollutants have been surveyed, data has been tabulated, and the effect of various emissions discussed. At this time certain general conclusions are evident.

Two types of pollutant problems exist in Edmonton: area and local. Area problems result from total emissions which in the Edmonton case generally appear to be low, with the exception of hydrocarbons. The emission of hydrocarbons appears to be approaching a level which could contribute to area pollution problems. The effect of combinations of pollutants is not predictable, but significant emissions of photochemically active compounds are experienced in Edmonton.

Although total emissions are low, the emission rates are higher than one would expect for a city this size. This is undoubtedly due to the high degree of industrialization which exists in Edmonton. It is impossible to accurately predict future industrialization, but it is estimated that if past trends (in respect to industry type and quantity) continue, area pollution problems will occur at lower growth levels than experienced elsewhere, and can be expected in the not too distant future.

There are a number of industries in the Edmonton area which are capable of causing local pollution problems. These are generally emitters of smoke, particulate matter, or odorous material. Although the problems associated with these compounds can be severe, they generally affect only a small portion of the population. This does not imply, however, that control is not necessary.

The following pages outline detailed recommendations which the writer feels are necessary to help prevent adverse pollution in Edmonton.

1. Hydrocarbon Control

The survey has indicated that hydrocarbon emissions are great enough to cause adverse pollution under certain weather conditions. Since hydrocarbons participate actively in smog formation the following control measures should be considered:

A. The elimination of open burning as soon as possible.

B. The discontinuation of the use of single chambered incinerators. Recommended standards for the construction of acceptable incinerators have been established and these could be used as minimum requirements for incinerators.

C. The conversion of some 500 industrial and commercial single chambered incinerators to acceptable units.

D. The prohibition or at least discouragement of the installation of domestic incinerators.

E. Partial control of hydrocarbon emissions from the petroleum and petrochemical industry. Partial control is considered sufficient at this time and a more complete form of control may be necessitated in the future.

F. Co-operative studies should be carried out to ensure that the municipal incinerator is operating at maximum efficiency.

G. A survey of organic solvent users in the area is necessary to complete the hydrocarbon emission estimate.

2. Expansion of the Atmospheric Monitoring Network

At the present time it is suspected that under inversion conditions smog may be present in the Edmonton atmosphere. Increases in population and the industrial complex are expected to add to the problem. It would be advantageous to add the following observations to those presently being made.

A. Oxidant analysis - Data accumulated would be useful in evaluating the smog problem as it presently exists and determining the effect of control measures.

B. Inversion observations - These are considered essential to a better understanding of the smog problem.

C. Carbon Monoxide - Carbon monoxide observations are useful in evaluating smog formation, and in determining the degree of control required to eliminate photochemical pollution.

D. Aldehydes - These compounds are second in importance to nitrogen oxides as photodissociators.

3. Increase Source Sampling Surveys

These are considered necessary for three reasons:

A. to insure that existing industries are meeting regulations and that collection equipment is operating at optimum efficiency.

B. to evaluate emission estimates used in this survey.

C. to compile a store of historic data for future use.

4. Control of Emissions Which Cause Local Pollution Problems

A number of industries exist which emit compounds which are capable of causing local problems. Recommendations for control of such sources include:

A. It should be required that all asphaltic concrete plants located in the Edmonton area provide secondary collectors.

B. Surveys of odor sources in such industries as plastic processors, petroleum, petrochemical, food processing and rendering should be carried out to locate and evaluate odor sources. Where local conditions indicate necessity, control should be required.

C. The use of certain noxious fume producing fluxes should be prohibited in the metal melting industry.

5. Control of Motor Vehicle Emissions

Until the Canadian motor vehicle industry indicates its intention in regard to exhaust devices, it is impossible to recommend action in respect to this source. Therefore the industry should be contacted and requested to indicate its intention. If voluntary controls are forthcoming it is estimated that the effect of used cars will be counteracted by the reductions brought about by incinerator control.

6. Control of New Industry

In order to maintain pollution at acceptable levels it is necessary that new industrial facilities located in the city provide adequate control devices. The present requirements for approval are considered adequate control measures at this time.

7. Industry Information and Education

Air pollution education of industry is an effective pollution control tool. Effort should be made to keep industry well informed of air pollution problems and developments by the use of short courses and the circulation of data.

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- (12) Haagen-Smit, A.J., Industrial and Engineering Chemistry, June 1952.
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- Appendix A -

S U R V E Y F O R M S

Government of the Province of Alberta
Department of Public Health
Division of Sanitary Engineering

Administration Bldg.,
May 6th, 1964.

Dear Sir:

During the past years a great deal of public interest in air pollution control has been generated in the Edmonton area. As interest grew so did the number of pollutant sources, and as a result a greater amount and variety of material is being released to the atmosphere yearly.

The control of atmospheric pollution in Alberta is the joint responsibility of Local Health Departments and the Division of Sanitary Engineering. Both groups are responsible for the administration of the Provincial Board of Health's "Regulations for the Control of Air Pollution". A copy of the regulations is enclosed for your information.

Initial air pollution studies were begun in the Edmonton area some five years ago. At that time an air monitoring programme was established, using the staff and facilities of the Division of Sanitary Engineering, the City Health Department, and Health Units adjacent to the city. As a continuation of the initial programme, the City of Edmonton Health Department and the Division of Sanitary Engineering are presently attempting a co-operative appraisal of the present, and potential air pollution problems in the Edmonton area. The industrial questionnaire which is enclosed is designed to provide information on the presently existing pollutant sources, and the total volume and type of pollutants being released to the air over Edmonton. It is hoped that data collected in this manner will be useful in establishing the most intelligent control programme possible, in setting objectives of the pollution control programme, and in insuring that Alberta air pollution control legislation is as modern and fair as possible.

We urgently request your co-operation in filling out the questionnaire and returning it in the enclosed envelope before June 1, 1964.

All information will be kept confidential, will not be reported in specific detail, nor will any specific industrial establishment be referred to by name. An extra copy of the questionnaire has been enclosed for your files.

In the event that you wish to discuss this matter, do not hesitate to contact us.

GOVERNMENT OF THE PROVINCE OF ALBERTA
Department of Public Health
Division of Sanitary Engineering

Administration Building,
June 4th, 1964.

Dear Sir:

On May 15th, 1964 a letter containing an atmospheric pollution source questionnaire was sent to you. When this study was initiated, we had hoped to have collected all the necessary data by June 1st, 1964. To date, roughly 75% of the 210 industries contacted have completed the questionnaire, and returned it. On checking our files I note that your questionnaire has not been returned. Since the success of this study is dependant upon a high return of data we are most anxious to receive your completed questionnaire. If you have encountered any difficulties in completing the form, please contact me and I will endeavour to clear up any problems you might have. If you have already returned the questionnaire, please excuse and disregard this letter.

Your co-operation and assistance will be sincerely appreciated.

INDUSTRIAL QUESTIONNAIRE

EMISSIONS SURVEY

Company Name _____

Address _____

Name and title of person to be contacted on pollution matters:

Phone No. _____

General Plant Information

(A) What is the address or location of your plant? (If different from the address reported above).

(B) What are your products or services? (Please indicate quantity produced per year).

(C) What raw materials do you use? (Indicate quantity consumed per year).

(D) Approximately how many employees do you have?

1 - 8 _____ 9 - 19 _____ 20 - 49 _____ 50 - 99 _____

100 - 249 _____ 250 - 449 _____ 500 - 749 _____

750 - over _____

3) Throughput Factor, K_f

Tank turnovers per year	K_f for general refinery service	K_f for marketing plants and terminals
0 - 10	1.00	1.00
12	.91	1.00
15	.75	1.00
20	.59	1.00
25	.50	1.00
30	.47	1.00
40	.44	1.00
40 - 60		.30
60 - 100		.50

4) Floating Roof Factor, C

Shell construction	Seal	C
Welded	Single or double	0.49
Riveted	Double	.56
Riveted	Single	1.20

The equations for fixed roof tanks are based on the following assumptions:

- Roofs are vapor-tight.
- Vents, gauge hatches, and other accessories are vapor-tight.
- Tanks operate at essentially atmospheric pressure; i.e., with vent pressure and vacuum settings in the order of 0.5 ounce per square inch.
- The volume under the roof is essentially the same as the volume under a low pitch conical roof having a slope of $\frac{3}{4}$ inch per foot.
- The mean daily temperature change is 16°F.

The equations used for estimating losses from floating roof tanks are based on the following assumptions:

- Average wind velocities are 5 to 10 miles per hour.
- Tanks are in good condition.
- Tank shells and roofs are painted aluminum or gray.
- Tanks are 8 to 20 years old and have sealing rings of the type which were in use at the time of their construction.

(E) What is your normal operating schedule?

hrs./day _____, days/week _____ months/year _____

Do you have an annual shut-down? Yes _____ No _____

If so, when? From _____ to _____

(F) Please tabulate your fuel and energy consumption per year.

Type of Fuel	Space Heating	Power Generation	Processing	Total
Natural Gas	_____ ft ³	_____ ft ³	_____ ft ³	_____ ft ³
Fuel Oil	_____ bbl	_____ bbl	_____ bbl	_____ bbl
Other (specify)	_____	_____	_____	_____

3. Air Pollution Information

(A) Do you have any stacks equipped with sample ports, ladders or platforms?

(B) What is the approximate quantity of your combustible waste material?

tons/year _____ cu. ft./year _____

What type of waste (e.g. waste paper, wood scrap)?

How much of this material is incinerated or burnt on your premises?

How is it incinerated (e.g. single chambered incinerator, burn pit, etc.)?

(C) Are you using odor control additives? Yes _____ No _____

Explain _____

(D) Do you use any organic solvents, dilutents, or thinners (e.g. alcohol, acetone, varsol)? Yes _____ No _____

If so, what solvent and how much do you use per year?

(E) How much (if any) weight did you lose?

- b) Please describe the material emitted to the atmosphere from your operation. Estimate the quantities emitted and describe any control equipment used for each process or operation as indicated below. If you are unable to provide answers to this part of the questionnaire please proceed to Question (E). If you require more space than that provided please use additional pages.

Process or Operation Causing Emission	Pollutants Emitted to Atmosphere			Collector or Other Control Equipment		
	Dust Droplet	Gas	Weight % or Volume % Per Year	Type	Rated Capacity	Cleaning Efficiency % Installed
Example	Example	Example	Example			
1. Hot Mix Asphalt Plant	From Main Stack	None	1.00 lbs. per 1000 lbs. flue gas	Pioneer Equipment Spray Tower	Up to 6.0 lbs. per 1000 lbs. @ 5,000 cfm	92 May 2/52

(E) It is not necessary to answer this section if you have completed (D). Please describe the various process equipment which is vented to the atmosphere at your plant.

Process or Operation Causing Emission	Rated Capacity of Unit	Raw Materials Used Type-Quantity	Finished Products Type-Quantity	Collector or Other Control Equipment		
				Type	Rated Capacity	Cleaning Efficiency % Installed
<u>Example</u>	<u>Example</u>	<u>Example</u>	<u>Example</u>	<u>Example</u>	<u>Example</u>	<u>Example</u>
1. Concrete Batching Plant	50 tons/hr.	Gravel 20-30 tons/hr. Sand 10-20 tons/hr. Cement 10 tons/hr.	Concrete 50 tons/hr.		None	None

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- Appendix B -

I N D U S T R I A L C L A S S I F I C A T I O N S

INDUSTRIAL CLASSIFICATIONS

1. PETROLEUM AND PETROCHEMICAL DEVELOPMENT, PROCESSING AND MARKETING

1. Refineries
2. Bulk Gasoline Marketing Facilities
3. Petroleum Production and Related Operations
4. Bulk Storage of Petroleum Distillates
5. Asphalt Manufacturing and Felt Saturators
6. Heavy Hydrocarbons, e.g. Blending, Compounding and Marketing of Fuel Oils, Asphalt, Grease, Lube Oils, Road Oils, etc.
7. Re-refiners, Solvents and Lube Oil
8. Petrochemical Manufacturing
9. Sulfur Recovery Plants

2. INDUSTRIAL CHEMICAL MANUFACTURING AND PROCESSING (EXCLUDING PETROCHEMICAL)

1. Soaps and Detergents
2. Insecticides and Herbicides, Compounding and Packaging
3. Chemical Specialties, e.g. Compounding and Packaging of Pharmaceuticals, Cosmetics, Aerosols, Household and Janitorial Chemicals, etc.
4. Industrial and Automotive Chemicals
5. Manufacturing and Packaging of Gases
6. Explosives, Rocket Propellants and Pyrotechnics
7. Radio Active Materials, Isotopes and Related Materials
8. Chemical Processes Involving Chlorination
9. Catalysts
10. Organic Chemicals
11. Inorganic Chemicals

3. FOOD PROCESSING

1. Meat Smoking, Packing, Canning, including Lard Rendering
2. Fish Smoking and Canning (excluding by-products)
3. Bakeries
4. Coffee Roasting
5. Dairy Products Processing including Dried Milk, Condensed Milk, Ice Cream etc.
6. Grain and Feed Milling, Flour Milling, Cereal Packaging, etc.
7. Fruit and Vegetable Canning and Packaging
8. Beverage Manufacturing
9. Pet Foods, All Types
10. Food Specialty Packaging, e.g. Spices, Condiments, Flavorings, etc.
11. Margarine and Oleaginous Products

4. INEDIBLE ANIMAL AND VEGETABLE BY-PRODUCT PROCESSING

1. Rendering
2. Fertilizer Processing and Packaging
3. Fish Cannery By-Products Processing
4. Tanneries and Hide Processing
5. Wool Processing
6. Dehydrating Food By-Products

5. PAINTS AND RELATED MATERIALS, MANUFACTURING AND HANDLING

1. Paint Type Products, e.g. Lacquer, Varnish, Stellite, Ink, Enamel, Powder Paints, Water Emulsion Paints, etc.
2. Paint Additives, e.g. Pigments, Dryers, Surfactants, etc.
3. Polymers and Resinous Materials
4. Marketing of Solvents and Liquid Chemicals
5. Vegetable and Animal Oil Processing (excluding Rendering and Food Processing)
6. Adhesives, e.g. Sealants, Patties, Calking Compounds, Masking Compounds, etc.

6. PLASTIC, RUBBER AND RESIN PROCESSING

1. Rubber Products Processing, e.g. Molding, Dipping, Coating, etc. (excluding tires)
2. Rubber Reclaiming
3. Tire Recapping
4. Plastic and Resin Molding, e.g. Injection Molding, Extrusion Molding, Permanent Molding, etc.
5. Plastic and Resin Fabrication, e.g. Laminating, Coating, Embedding, Sheet Forming, etc.
6. Tire Manufacturing

7. METAL MELTING AND RECLAIMING

1. Grey-Iron Foundry Facilities
2. Steel Foundry Facilities
3. Brass Foundry Facilities
4. Aluminum Foundry Facilities
5. Magnesium Foundry Facilities
6. Miscellaneous Non-Ferrous Foundry Facilities
7. Secondary Refiners
8. Core Making Facilities
9. Die Casting Facilities

8. SURFACE FINISHING AND COATING

1. Galvanizing Facilities and Plants including Dip Tinning
2. Sand Blasting and Abrasive Blasting Facilities
3. Heat Treating Plants
4. Printing on Metal
5. Plating Facilities
6. Surface Coating and Protective Treating of Materials, e.g. Pickling, Parkerizing, Bonderizing, Corrosion Preventive Coatings, Vacuum Coating, Metallizing, Anodizing, etc.
7. Surface Grinding and Polishing, e.g. Centerless, Surface, Lapping, Honing, etc.
8. Painting and Enamelling, Major Users
9. Display Sign Manufacturing and Servicing

9. MINERAL PROCESSING

1. Sand and Gravel Plants, Rock Plants, Concrete Batch Plants, Cement Storage and Handling Facilities
2. Asphalt Paving Plants, e.g. Hot Plants
3. Ceramic Processing, e.g. Brick, Tile, Clay Products, Refractories, etc.
4. Glass, Frit and Rock Wool Manufacturing, including Vermiculite and Perlite Plants
5. Mixing, Grinding, Blending and Packaging of Miscellaneous Mineral Base Products

10. WOODWORKING AND FURNITURE MANUFACTURING

1. Lumber Yards, including Sash and Door Mills
2. Furniture Manufacturing, Repairing and Refinishing, including the Use of all Materials
3. Casket and Cabinet Shops
4. Wood Treating Facilities, e.g. Termite Proofing, Creosoting, Flame Proofing, etc.
5. Pattern Shops, All Types
6. Wood Turning Facilities
7. Wood Shipping Materials, e.g. Pallets, Crating, Skids, Cooperage, etc.
8. Wood Laminating, e.g. Plywood Veneering, Formica Bonding, etc.
9. Wood By-Products Plants, e.g. Sawdust, Wood Flour, Shaving, Briquets, etc.

11. COMMERCIAL ACTIVITIES

1. Retailing Activities, Consumer Sales and Equipment Rentals
2. Wholesalers, Jobbers, Warehouses and Contractors' Yards
3. Electrical and Electronic Repairing, Rebuilding and Servicing
4. Motion Picture and Television Production Facilities
5. Photographic Arts and Processing, e.g. Studios (excluding Motion Picture and TV), Film Laboratories, Commercial Artists, Photo Duplicating including Blueprinting and Ozalid
6. Laundries, Rub Cleaning, etc.
7. Cafes, Restaurants and Bars (excluding those in hotels)
8. Printing Shops, Newspapers and Publishers
9. Mortuaries, Crematories and Cemeteries
10. Graphic Arts Specialties and Services, e.g. Engravers, Photoengravers, Electrotypers, Mat-makers, Silk Screening, Printed Circuits, etc.
11. Dry Cleaning Plants
12. Junk Yards, Salvaging and Converting of Industrial Materials (excluding Secondary Metal Refining)
13. Business Machines, Sales and Servicing
14. Household Appliances, Sales and Servicing
15. Amusement and Recreational Facilities
16. Agricultural Operations

12. VEHICLE MANUFACTURING AND SERVICING FACILITIES

1. Airframe Production including Guided Missiles
2. Auto and Truck Assembling
3. Trailer Manufacturing and Assembling
4. Aircraft Overhaul Facilities
5. Automotive Component Rebuilding Facilities, e.g. Engines, Transmissions, Carburetors, Starters, Generators, Water Pumps, etc.
6. Custom and Special Vehicle Manufacturing (excluding Trucks and Trailers)
7. Auto Wreckers
8. Vehicle Dealers
9. Vehicle Repair Facilities including Vehicle Body Repair Shops
10. Shipyards, Boat Building, Boat Repair, Dry Docks, etc. (excluding Governmentally Owned)
11. Railroad Service and Repair Facilities, Yards, Roundhouses, etc. (excluding Stations, Depots and Warehouses)

13. METAL FABRICATING

1. Electrical and Electronic Equipment Manufacturing
2. All Instrument Manufacturing, Repairing and Rebuilding
3. Structural Metal Fabricating and Forming
4. Sheet Metal Fabricating, e.g. Punch Pressing, Drawing, Metal Spinning, Tube Drawing, etc.
5. Welding, Blacksmithing, Forging, Swaging, Cold Heading, Upsetting, etc.
6. Heavy Machinery Manufacturing and Reconditioning
7. Metal Cutting, e.g. Machine Shops, Tool and Die Shops, Oil Tool Manufacturing and Reconditioning, etc.
8. Battery Manufacturing, Assembling and Rebuilding
9. Wire Products Manufacturing, e.g. Springs, Cables, Wire Forms, Metal Cloth, Wire Drawing, etc.
10. Powdered Metal Processing

14. TEXTILE, FABRIC, FIBER, MONOFILAMENT MANUFACTURING AND PROCESSING

1. Garment Manufacture
2. Textile and Fabric Coverings Manufacturing, e.g. Seat Covers, Tents, Tarpaulins, Draperies, Awnings, etc.
3. Textile and Fabric Processing, e.g. Sponging, Shrinking, Waterproofing, Dyeing, Flameproofing, Printing, etc.
4. Mattress, Cushion and Pad Manufacturing and Renovating (excluding Furniture Manufacturing)
5. Paper Products
6. Shoe and Luggage Manufacturing, etc.
7. Brush Manufacturing
8. Special Textiles, e.g. Felt, Webbing, Rope, Cordage, Packings, Oakum, Belting, etc.
9. Weaving of Textile Materials, e.g. Braid, Tape, Lace, Bindings, Rugs, etc.

- Appendix C -

Emission Factors for Petroleum Refining

Factors for Particulate Emissions

Source	Units of Factor	Value
Boilers and process heaters	Pounds per 1000 cu. ft. of fuel gas burned	0.02
	Pounds per barrel of fuel oil burned	.8
Fluid catalytic units:		
With electric precipitation	Percent of catalyst circulated	.0009
Without electric precipitation	Percent of catalyst circulated	.005
Moving-bed catalyst units, high efficiency centrifugal separators.	Percent of catalyst circulated	.002

Factors for Emissions of Nitrogen Oxides, Carbon Monoxides, Aldehydes, and Ammonia From Oil Refineries

Source	Units of Factor	Value of Factor for Various Emissions			
		NO _x as NO ₂	CO	Aldehydes as HCHO	Ammonia as NH ₃
Boilers and process heaters	Pounds per 1000 cu. ft. of fuel gas burned.	0.23	Neg.	0.0031	Neg.
	Pounds per barrel of fuel oil burned.	2.9	Neg.	.025	Neg.
Compressor internal combustion engines.	Pounds per 1000 cu. ft. of fuel gas burned.	.86	Neg.	.11	0.2
Fluid-bed catalytic cracking units.	Pounds per 1000 barrels of fresh feed.	63	13,700	19	54
Moving-bed catalytic cracking units.	Pounds per 1000 barrels of fresh feed.	5.0	3,800	12	5.0

Factors for Hydrocarbon Emission From Combustion Sources

Source	Units of factor	Value
Boilers and process heaters	Pounds per 1000 cu. ft. of fuel gas burned	0.026
	Pounds per barrel of fuel oil burned	.14
Fluid catalytic cracking units	Pounds per 1000 barrels fresh feed	220
Moving-bed catalytic cracking units	Pounds per 1000 barrels fresh feed	87
Compressor internal combustion engines	Pounds per 1000 cubic feed of fuel gas burned	1.2

Factors for Hydrocarbon Emissions from Equipment Leakage

Source	Units of Factor	Value
Pipeline valves	Pounds per day per valve	0.15
Vessel relief valves	Pounds per day per valve	2.4
Pipeline relief valves		Neg.
Pump seals	Pounds per day per seal	4.2
Compressor seals	Pounds per day per seal	8.5
Pipeline valves	Pounds per 1000 barrels refinery capacity	28
Vessel relief valves	Pounds per 1000 barrels refinery capacity	11
Pump seals	Pounds per 1000 barrels refinery capacity	17
Compressor seals	Pounds per 1000 barrels refinery capacity	5

Factors for Hydrocarbon Emissions from
Miscellaneous Process Equipment

Source	Units of Factor	Value	Range of values
Blowdown systems	Pounds per 1000 barrels refining capacity		5-300
Process drains and waste water separators	Pounds per 1000 barrels waste water processed		8-210
Vacuum jets	Pounds per 1000 barrels vacuum distillation capacity		0-130
Cooling towers	Pounds per million gallons cooling water circulated	6	
Other	Pounds per 1000 barrels refinery capacity	10	

Method for Calculating Hydrocarbon Vapor Losses From Storage Tanks

Many methods for calculating hydrocarbon losses from storage tanks have been developed by various groups from experimental studies.

The equations used for making the calculations are as follows:

1) Breathing Losses From Fixed Roof Tanks

$$B = \frac{PD^{1.8}}{14.5} F_o F_p$$

2) Filling Losses From Fixed Roof Tanks

$$F = \frac{3PV}{10,000} K_f$$

3) Evaporation Losses From Floating Roof Tanks

$$E = CPD$$

4) Filling Losses From Floating Roof Tanks

$$F_e = \frac{V}{10,000}$$

- where: B = breathing loss from a fixed roof tank, in barrels per year.
F = filling loss from a fixed roof tank, in barrels per year.
E = evaporation loss from a floating roof tank, in barrels per year.
F_e = filling loss from a floating roof tank, in barrels per year.
P = true vapor pressure at the average liquid body temperature, in pounds per square inch absolute.
D = tank diameter, in feet.
V = volume of liquid product added to the tank, in barrels per year (in the case where product is being withdrawn simultaneously with product addition, V is the excess of addition over withdrawal).
F_o = outage factor for fixed roof tanks.
F_p = paint factor for fixed roof tanks.
K_t = throughput factor.
C = floating roof factor for type of shell construction, seal, and roof.

Values to be used for the outage, paint, throughput, and floating roof factors are:

1) Outage Factor, F_o

$$F_o = \frac{1}{5.7} (H + 5)^{0.57} - 0.1$$

where: H = outage, or height between top angle of the tank and the liquid surface, in feet.

A table of outages versus outage factors prepared from the equation is as follows:

H	F_o
1	0.39
5	0.55
10	0.72
15	0.87
20	1.00
25	1.12
30	1.23
35	1.33
40	1.43
45	1.53
50	1.62

Some adjustments may have to be made to the outage value used if the volume under the tank roof is much different from the volume under a conical roof with a pitch of $\frac{3}{4}$ inch per foot. A larger volume will call for a higher outage, and a lower volume a lower outage.

2) Paint Factor, F_p

Paint	F_p
Chalking white	0.75
Aluminum	1.00
Light gray	1.10
Black, no paint, or needs repainting	1.25

- Appendix D -

E M I S S I O N S F R O M I N C I N E R A T O R S

Appendix D - Emissions from Incinerators

Compound or Group	Emissions - lbs./ton of charged material	
	Single Chamber (1)	Multiple Chamber (2)
Methanol	9-23	less than .05
Athylene	8-61	less than .05
Acetone	less than 8	less than .05
Methane	23-150	less than .05
Acetylene	less than 4-73	less than .05
Alpha Olefins (as propylene)	less than 6	less than .05
Carbonyl Sulfide	greater than 3	less than .05
Benzene	greater than 3	less than .05
Acids (as acetic)	greater than 4	less than .05
Phenols (as phenols)	greater than 8	less than .05
Aldehydes (as formaldehyde)	5-64	approximately .3
Ammonia	0.9-4	less than .05
Oxides of Nitrogen (as NO ₂)	less than 0.1	approximately 2.1
Carbon Monoxide	197-990	less than .05
Particulate Matter	15.3-22.4	2.0

Emissions from Municipal Incinerators

Compounds	Emissions - lbs./ton of charged material
Particulate Matter	21.9
Hydrocarbons	0.8
Carbon Monoxide	0.52
Nitrogen oxides (NO ₂)	2.7
Formaldehyde	.0026

Losses listed less than .05 lbs./ton were below the detectable limit.

- (1) Mocom, J.E., Hein, G.M., & Nelson, H.W. "A Study of Effluents from Backyard Incinerators", Journal of the Air Pollution Control Association Vol. 6, No. 2, P. 89, (August 1956).
- (2) Test information from files of Research Division, Air Pollution Control District, County of Los Angeles.
- (3) Stenburg, R.L., Hangebrauck, R.P., Von Lehmden, D.J., and Rose, A.H. Jr. "Field Evaluation of Combustion Air Effects on Atmospheric Emissions from Municipal Incinerators", Journal of the Air Pollution Control Association, Vol. 12, No. 2, Feb. 1962.

- Appendix E -

Motor Vehicle Emission Factors
Exhaust Losses - Gasoline Engines

Appendix E - Motor Vehicle Emission Factors
Exhaust Losses - Gasoline Engines.

Estimates of auto-exhaust emission in Los Angeles County as of January 1961 are as follows:

Compound	Emissions lbs. per U.S. gallon of gasoline consumed
Carbon monoxide	3.0
Hydrocarbons	0.2 - 0.4
Nitrogen oxides	0.05 - 0.15
Aldehydes	.005
Organic acids	.002
Ammonia	.002
Solids	.0003

Assuming that driving conditions are similar, that engine age and repair is similar, and that a similar type of gasoline is used, these figures should be applicable to Edmonton. Sulfur dioxide is also emitted from auto exhausts, and is a function of the sulfur content of the gasoline, which in turn is dependent on the sulfur content of the crude oil entering the refinery. The average sulfur content of gasoline produced in Edmonton refineries ranges from .007 to .06 percent by weight. Assuming worst conditions (i.e. sulfur content of .06%), and 100% conversion of the sulfur to SO₂, sulfur dioxide emissions should be 0.0072 lbs./gallon of gasoline (U.S.).

Gasoline Tank Losses (1)

Hydrocarbon losses, resulting from fuel tank displacement and evaporation are expected to approximate .45 lbs./day/tank.

However, the mean annual temperature in Edmonton is about 40°F (3) and Chambers (2) states that at temperatures below 80°F losses from this source are considered to be small in the Edmonton area.

Carburetor Operating Loss (1)

Calculation is based on the assumption that 0.6% of the supplied fuel is lost and that 80% of the vehicles have carburetor vents. Total loss is therefore .6% x 80% x gasoline consumption in tons. This factor is assumed for an average ambient temperature of 86°F. Losses in Edmonton are assumed to be negligible for the same reasons mentioned in the section on gasoline tank losses.

Carburetor Hot Soak Loss (1)

Based on an average loss of 0.01 lbs. from each occurrence, and the assumption that an average of 2 hot soaks occur per day for 50% of the registered vehicles.

Diesel Emission Factors

Emissions will vary with driving conditions and motor repair or maintenance. Factors are similar to those reported in the report entitled Pure Air for Pennsylvania (4).

Compound	Emission lbs./gallon of fuel
Oxides of nitrogen	0.222
Aldehydes	0.016
Organic acids	0.031
Hydrocarbons	0.715
Particulates (non-ether soluble)	0.086

Sulfur oxide emissions depend upon the sulfur content of the fuel which is approximately .02 to .1% by weight. Assuming 100% conversion and the worst case (.1%) sulfur dioxide emission is expected to be .014 lbs. per gallon of fuel.

Other Sources

Hydrocarbons are lost when various gasoline handling operations are carried out. Losses resulting from refinery loading are included in the section on Petrochemical and Petroleum Industries. Further losses are experienced as a result of filling service station tanks and auto tanks (breathing losses). These are estimated to be .0214 lbs. per gallon of gasoline handled.

References

- (1) State of California, Department of Public Health, Technical Report of California Standards for Ambient Air Quality and Motor Vehicle Exhaust, December 1959.
- (2) U.S. Department of Health, Education, and Welfare, Proceedings of the National Conference on Air Pollution, November 1958.
- (3) Meteorological Branch, Department of Transport, The Climate of Canada, 1960.
- (4) Pennsylvania Department of Health and the U.S. Department of Health, Education and Welfare, Pure Air for Pennsylvania, November 1961.

- Appendix F -

Summary of Pollutant Emissions in
the Edmonton Area

Appendix F - Summary of Pollutant Emissions in the
Edmonton Area

Emissions
Industrial Group

Compound	Petroleum & Petrochemical Processing		Industrial Chemical Manufacturing		Food Processing		Inedible Animal & Vegetable Processing	
	tons/yr.	% of total	tons/yr.	% of total	tons/yr.	% of total	tons/yr.	% of
Total Hydrocarbons	50,730	57.3						
SO ₂	2,969	61.2	1,589	32.8				Odors
Particulate matter	1,074	9.9	356	3.3	205	1.8		only
Carbon monoxide	63,227	27.6	-					
NO _x	1,728	11.1	-					
Aldehydes	79	1.7	4	.1				
NH ₃	217	17.6	710	57.4				
Other Organics	1,741		-					
Acetylene			2	100				
Phenol			2	.4				

Paints & Related Materials Mfg.	Plastic, Rubber & Resin Processing	Metal Melting	Surface Finishing & Coating	Mineral Processing
---------------------------------------	--	------------------	-----------------------------------	-----------------------

Total Hydrocarbons

SO₂ Not

Particulate matter Odors 1,546 14.3 0.5 n 5,206 48.1

CO

NO_x

Aldehydes available

NH₃

Other Organics 1.5

Acetylene

Phenol

	Woodworking & Furniture Manufacturing	Commercial Activities	Vehicle Mfg. & Servicing	Metal Fabricating	Textile, Fabric, Etc. Mfg. & Processing		
Total Hydrocarbons							
SO ₂							
Particulate matter	Solvent	Solvent	Solvent	Solvent	306	2.8	
CO	Emissions	Emissions	Emissions	Emissions			
NO _x							
Aldehydes					.2	n	
NH ₃							
Other organics							
Acetylene							
Phenol					.2	n	

	Disposal of Garbage and Refuse		Fuel Usage		Motor Vehicle		T o t a l	
							tons per year	tons per day
Total Hydrocarbons	18,399	20.8	2065	2.8	17,045	19.0	88,293	242
SO ₂	na		n		291	6.0	4,849	19
Particulate Matter	1,927	17.8	n		192	1.8	10,812	30
CO	56,166	24.6	n		109,206	47.8	228,599	791
NO _x	87	.6	6019	43.7	5,927	43.1	13,763	38
Aldehydes	3,631	77.3	686	14.8	216	4.6	4,616	13
NH ₃	227	18.3	7.6	.7	73	5.5	1,234	3
Other Organics	na		n				1,742	5
Acetylene	na		n				2	n
Phenol	454	99.6	n				456	1

n - negligible

na - not available

- Appendix G -

Derivation of Equation for Calculation
of Ground Level Concentrations Resulting
from Pollutant Emissions in Edmonton

Appendix G - Derivation of Equation for Calculation
of Ground Level Concentrations Resulting
from Pollutant Emissions in Edmonton

The differential equation describing the addition of contaminants at a rate Q into a moving volume of air (WLH) moving at a rate of $(WH\bar{u})$ is:

$$(WLH) \frac{dX}{dt} = Q - (WH\bar{u})X$$

The solution to this equation is:

$$\bar{X} = \frac{Q}{WH\bar{u}} \left(1 - e^{-\frac{\bar{u}t}{L}} \right)$$

The factor 1.3 is added to account for the efficiency of mixing, following accepted ventilation methods. Therefore:

$$\bar{X} = 1.3 \frac{Q}{WH\bar{u}} \left(1 - e^{-\frac{\bar{u}t}{L}} \right)$$

Symbols: W = width of volume of air, M.

H = height of volume of air from ground to top of inversion, M.

\bar{u} = average wind speed, M./sec.

Q = rate of pollutant emission, gm./sec.

t = time, sec.

L = length of volume of air, M.

e = base of Napierian logarithms (2.718).

X = concentration of pollutant in air, gm./cu. M.

All in consistent units.

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